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AD-A262 426



Technical Report EL-93-2
January 1993

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Phase II Studies: Impacts of Commercial Navigation Traffic on Freshwater Mussels at the W. H. Zimmer Station, 1991 Studies

by Andrew C. Miller, Barry S. Payne
Environmental Laboratory

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Final report

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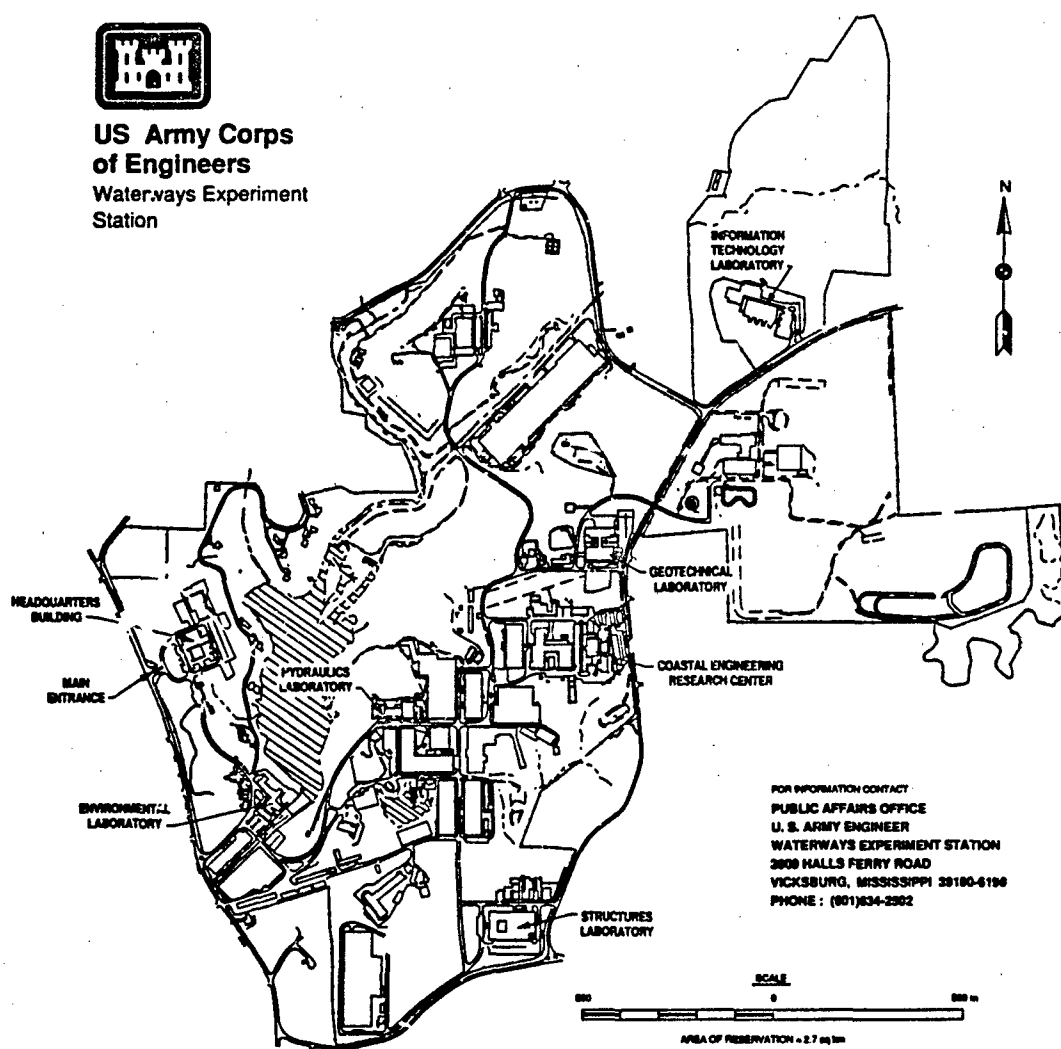
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**US Army Corps
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Waterways Experiment
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Waterways Experiment Station Cataloging-in-Publication Data

Miller, Andrew C.

Phase II studies : impacts of commercial navigation traffic on fresh-water mussels at the W.H. Zimmer Station, 1991 studies / by Andrew C. Miller, Barry S. Payne ; prepared for Mussel Mitigation Trust.

67 p. : ill. ; 28 cm. — (Technical report ; EL-93-2)

Includes bibliographical references.

1. Freshwater mussels — Effect of sediments on. 2. Unionidae — Effect of habitat modification on. 3. Inland navigation — Environmental aspects — Ohio — Cincinnati. 4. Mussels — Effect of water quality on. I. Payne, Barry S. II. Mussel Mitigation Trust. III. U.S. Army Engineer Waterways Experiment Station. IV. Title. V. Title: Impacts of commercial navigation traffic on freshwater mussels at the W.H. Zimmer Station, 1991 studies. V. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; EL-93-2.

TA7 W34 no.EL-93-2

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Preface

The Mussel Mitigation Trust funded the U.S. Army Engineer Waterways Experiment Station (WES), under Contract Number 108, to collect baseline data on freshwater mussels at the William H. Zimmer Station on the Ohio River near Cincinnati, OH. The purpose was to obtain information to evaluate impacts of increased barge traffic at the station, owned by Cincinnati Gas & Electric, Columbus Southern Power Company, and Dayton Power and Light Company. The Cincinnati Gas & Electric Company operates the station for three owners. This report describes data collected in 1991.

This report was prepared by Drs. Andrew C. Miller and Barry S. Payne of the Aquatic Ecology Branch (AEB), WES. Technical assistance was provided Ms. Sarah Wilkerson, AEB.

An early draft of this report was reviewed by a representative of the Cincinnati Gas & Electric Company, the Kentucky Department of Fish and Wildlife Resources, and the Ohio Department of Natural Resources.

During the conduct of the study, Dr. Edwin A. Theriot was Chief, AEB, Dr. Conrad J. Kirby was Chief, Ecological Research Division, and Dr. John Harrison was Director, Environmental Laboratory at WES.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Leonard G. Hassell, EN.

This report should be cited as follows:

Miller, Andrew C., and Payne, Barry S. 1993. "Phase II studies: Impacts of commercial navigation traffic on freshwater mussels at the W. H. Zimmer Station, 1991 studies," Technical Report EL-93-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

| Multiply | By | To Obtain |
|-----------------------|------------|-------------|
| degrees (angle) | 0.01745329 | radians |
| feet | 0.3048 | meters |
| gallons (U.S. liquid) | 3.785412 | liters |
| inches | 2.54 | centimeters |

1 Introduction

Background

The William H. Zimmer Station, located on the Ohio River near Cincinnati, OH, has been converted from nuclear to coal power. This required construction of a harbor and a loading facility for coal, lime, and fuel oil. Because of the possibility that a mussel bed located immediately downriver could be damaged by barge deliveries, data on freshwater molluscs were collected before the station began operation. The station began limited operation in 1990, and coal deliveries by barge started early that year. During its first year of commercial operation (March 1991-March 1992), the station burned eight to nine bargeloads of coal per day.

Data were collected in 1989, 1990, and 1991 on community characteristics, density, recruitment rates, and population demography of dominant species of freshwater molluscs in a bed immediately downriver of the station. In 1989, data were also collected on ambient water velocity over the mussel bed. In 1990, data were collected on the effects of passage of commercial navigation vessels (full-sized tugs usually with 15 or more barges) on ambient velocity. In 1991, changes in ambient water velocity, suspended sediments, and turbidity caused by operation of a workboat (*Pleasant*) that shuttles barges from the fleeting area to the coal unloader were measured. Data collected in 1989 and 1990 have already been published (Miller and Payne 1991).

Data collected in 1989 were indicative of baseline conditions before the station began operations. Data collected in 1990 can still be considered baseline conditions, since coal deliveries had just started. The data collected in 1991 reflect conditions during full operation of the plant. Future studies will be conducted after the plant has operated for several years, to determine if coal deliveries have measurable effects on the mussel community. Results will have to be interpreted cautiously. It is likely that, through time, the water and habitat quality of the Ohio River could be altered by the cumulative effects of multiple water resource projects located upriver.

Historical information on bivalves of the Ohio River can be found in Rhoads (1899), Keup, Horning, and Ingram (1963), Bickel (1966), Taylor (1980, 1989), Neff, Pearson, and Holdren (1981), and Tolin, Schmidt, and Zeto (1987). Williams (1969), Dames and Moore (1980), Williams and

Schuster (1982), Stansbery and Cooney (1985), and Environmental Science and Engineering (1988) studied molluscs at this bed.

Study Area

The study area is between river miles (RM) 444.2 and 445.6, which is about 0.8 km north of Moscow, Clermont County, OH, and 48 km southeast (upriver) of Cincinnati (Figure 1). The area is upriver of Markland Lock and Dam (L&D) (RM 531.5) and downriver of Meldahl L&D (RM 436.0). This river reach is a considerable distance downriver of industrial effluents from Pittsburgh (RM 0.0) and immediately upriver of those from Cincinnati.

Harbor construction affected only a small section of the mussel bed near the William H. Zimmer Station. At RM 444.2, immediately downriver of the first barge mooring cell (MC1), divers reported piles of sediment and evidence of physical disturbance (northernmost cell, Figure 1). This was probably caused by movement of the dredge and workboats, since no dredging took place downriver of MC1. The divers found no evidence of disturbance of the substratum 200 m or more downriver of this cell.

Methods

Molluscs were collected by a dive crew equipped with surface air supply and communication equipment. Qualitative samples were obtained by having three divers collect simultaneously. Each diver placed a specific number of live mussels in each of four nylon bags; five mussels were placed in the first bag, and 20 were placed in each of the other three bags. All mussels were brought to the surface, counted, and identified. Divers were instructed to exclude the Asiatic clam, *Corbicula fluminea* (Muller, 1774), from qualitative samples. Each diver collected approximately 65 live mussels (some shells and rocks were inadvertently taken), totaling approximately 185 mussels at each of six sites.

Ten quantitative samples (0.25 sq m), which included unionids as well as *C. fluminea*, were taken at each of four locations on the mussel bed. Samples were collected at an upriver and downriver site at RM 444.2 (referred to as 444.2-u and 444.2-d, which were about 100 m apart) and at RM 444.4 and 444.6. Collections were made at these sites during previous years. At each site, quadrats were placed approximately 1 m apart and arranged in a 2-by-5 matrix. A diver excavated all sand, gravel, shells, and live molluscs to a depth of 10 to 15 cm. Material was sent to the surface in a 5-gal¹ bucket and

¹ A table of factors for converting non-SI units of measurement to SI units is presented on page v.

transported to shore. Sediment was screened through a sieve series (finest screen with apertures of 6.4 mm).

All live bivalves were placed in 1-gal zipper-lock bags and preserved in 10 percent buffered formalin. In the laboratory, each mussel was identified and weighed to the nearest 0.01 g on a top-loading balance; total shell length (SL) was measured to the nearest 0.1 mm using dial calipers. Nomenclature for Unionidae was consistent with Turgeon et al. (1988). All *C. fluminea* in each sample were counted, and the total wet weight was recorded.

Data analysis

Species diversity was determined with the following formula:

$$H' = -\sum p_j \log p_j$$

where p_j is the proportion of the population in the j^{th} species (Shannon and Weaver 1949). Evenness was calculated by determining diversity on the sample while assuming that an equal number of individuals were distributed among each species (i.e., if there were 100 individuals and 10 species, each species would have 10 individuals present). Means, standard deviations, etc., were calculated using spreadsheets or programs written in BASIC or SAS (Statistical Analytical System) on a personal computer. Discussion of these standard statistical techniques can be found in Green (1979) and Hurlbert (1984).

Species area curves and dominance-diversity curves were constructed from qualitative and quantitative biological data. More information on these methods can be found in McNaughton and Wolf (1973), Hughes (1986), Isom and Gooch (1986), Kovalak, Dennis, and Bates (1986), and Miller and Payne (1988).

Growth studies

In 1990, growth studies were initiated at RM 444.4 and 444.6 using six demographically complete groups (all size groups present) of four species--*Quadrula pustulosa pustulosa* (L. Lea, 1831); *Amblema plicata plicata* (Say, 1817); *Pleurobema cordatum* (Rafinesque, 1820); and *Obliquaria reflexa* (Rafinesque, 1820).

For each species, shell length, shell height, and maximum body width were measured. In addition, the total number of rings (lines of growth) was counted when possible. Each mussel was engraved with an identifying letter and number, by using a dremel tool. At each location, three 0.25-m² aluminum quadrats were cabled together with approximately 5 to 7 m of 3/8-in.

coated wire rope. A diver then set each quadrat on the substratum and excavated all sediment, live bivalves, and shells from the enclosed area. Twenty liters of screened gravel (saved from the quantitative samples) and the marked mussels were then placed in each quadrat. Total density was equivalent to 100 individuals/m² in each enclosure, which was about twice the density at the mussel bed. The quadrats did not contain any live *C. fluminea*.

The three quadrats and connecting cable were parallel to the shore and about 35 m offshore. All distances were measured with an optical range finder. Exact location was determined by reference to standard features on navigation charts. In 1991, the quadrats with marked and measured mussels were collected and remeasured to determine growth rates.

Water velocity

Changes in water velocity were measured with Marsh McBirney model 527 current meters. The tip of each velocity probe was mounted in a concrete block, positioned, and secured by divers. Sensors 939, 946, and 942 were positioned to measure water velocity 20 to 25 cm above the substratum-water interface. Sensor 940 was positioned on a tripod so that it measured water velocity within 20 cm of the surface (Figure 1).

The sensor for the model 527 current meter measures velocity in two directions (X and Y components that are at right angles to each other) and is equipped with a compass. The compass, which is read from the meter, assists in positioning the sensor and can be used to calculate direction of flow. Each meter was equipped with a 1,000-ft spool of cable. Water velocity in two directions and the compass reading were obtained at 1-sec intervals and stored on a model CR10 data logger (Campbell Scientific, Inc., Logan, UT). In the field, all data were downloaded to a Toshiba lap-top personal computer and converted to ASCII files.

Magnitude of flow was calculated from individual velocity components by the formula

$$\text{Magnitude} = (X^2 + Y^2)^{0.5}$$

The resolved angle of water flow was determined by the formula

$$\theta = \tan^{-1} (X/Y) \quad \text{if } Y \geq 0$$

or

$$\theta = \tan^{-1} (X/Y) + 180 \text{ deg, if } Y < 0$$

Individual components of velocity, combined velocity, and direction of flow were plotted using a Macintosh computer and laser printer. More information on the Marsh McBirney 527 current meter and methods for calculating combined flow can be found in the instruction manual for the model 527.

Turbidity

Water for turbidity measurements was collected 10 cm above the substratum-water interface at selected distances downriver of areas where the workboat *Pleasant* was shuttling barges. Water was brought to the surface through a 25-ft length of rubber hose secured to a concrete block. Suction was provided by a 12-V Water Puppy pump. The pump ran continuously, and a 500-ml bottle was filled every 10 sec. Turbidity was measured immediately after each event in the field with a Hach turbidimeter. In addition, samples were returned to the laboratory on ice to measure total suspended solids. In the laboratory, an aliquot of water was filtered through preweighed 0.45- μm filters, dried at 105 °C, and weighed.

2 Physical Conditions

Effects of Operation of Workboat on Water Velocity and Suspended Sediment

At the William H. Zimmer Station, barges are typically moored three wide, to all but MC1 (the northernmost cell, see Figure 1). Mooring cells are approximately 200 ft apart at the northern end of the harbor. When barges take coal to the unloading facility, the workboat *Pleasant* moves downriver (away from its mooring site near the coal unloader), makes a sharp right turn toward the bank (180 deg), and heads toward the most downriver barge located closest to the channel. The *Pleasant* stays under minimal power while the crew secures the barge. The *Pleasant* then maneuvers the barge toward the channel and heads upriver to the unloader. The *Pleasant* always works from the channel toward the shore, and always from downriver to upriver.

Before the series of tests described below began (on 7 August 1991), barges were moored three abreast, starting at MC2. Sensor 942 was 20 ft downriver of MC1 and 220 ft downriver of MC2. The last fleet of barges was secured to MC2. Since the *Pleasant* was removing these barges secured to MC2, the sensors used were located between 220 and 470 ft downriver of the source of turbulence and turbidity. This can be considered the most upriver section of the mussel bed. Samples have been collected about 100 ft downriver of MC1, which contained moderate to high densities of mussels. Mussels are found along the right descending bank (RDB) downriver to at least RM 445.6 (Figure 1).

Discussion of Selected Testing Events

The following paragraphs present a discussion of selected events (movements of the *Pleasant* or commercial vessels in the area). Velocity and suspended sediment data were collected for 11 events during the 2-day period. Only the following representative events have been chosen for analysis.

Test 6

The most downriver end of two barges was moored to MC2. Immediately upriver of these two, barges were three abreast. The *Pleasant* moved in, secured to the barge closest to the channel, and maneuvered it upriver.

At Sensor 946, 130 ft downriver of MC1 and a total of 330 ft downriver of where the *Pleasant* was working, ambient velocity changed from approximately 0 fps to approximately 3 fps (Figure 2). Maximum velocity occurred 775 sec after the test started. At 270 ft downriver of MC1 (at Sensor 939), maximum velocity was approximately 2.8 fps, which occurred 850 sec after the start of the test. This period of maximum velocity occurred 75 sec after a velocity peak that was recorded at Sensor 946. This sensor was located farther upriver (see Figure 1). The combined or net velocity (taking into account the X and Y components of flow) changed in a similar manner at the sensors (Figure 3).

Changes in water velocity measured near the surface were very similar to those measured near the substratum-water interface. Compare the results obtained at Sensor 940, near the surface (Figure 4), with results obtained at Sensor 946, near the substratum-water interface (Figure 3). Turbidity changed from approximately 10 and 30 nephelometric turbidity units (NTU) near the surface and river bottom, respectively, to approximately 50 and 120 NTU near the surface and river bottom, respectively (Figure 4).

Test 7

In this test, the *Pleasant* moved in and removed the barge closest to the shore (Figures 5-8). Maximum velocity 130 ft downriver of MC1 was approximately 2.8 fps, 750 sec after the test began at Sensor 946. At Sensor 939, 270 ft downriver of MC1, maximum velocity was about 2.0 fps, 950 sec after the test began (Figure 5). Combined or net velocities behaved in a similar manner (Figure 6). At 130 ft downriver of MC1, maximum turbidity near the substratum-water interface was greater than 100 NTU for about 150 sec (Figure 8). The *Pleasant* disrupted velocity and suspended sediments for about 400 sec. Velocity or turbidity peaks appeared to last about 25 to 50 sec.

Test 9

In Test 9 the *Pleasant* removed the outermost of three barges (Figure 9). This activity took place a full bargelength upriver (100 ft) of barges moved during Tests 5 and 6; hence, changes in water velocity and turbidity were slightly less than those measured previously. At 130 ft downriver of MC1, water velocity changed from near ambient to about 0.6 fps (much less than changes caused by Tests 5 and 6). Maximum turbidity caused by the event did not exceed 40 NTU.

Test 11

In this test the *Pleasant* nudged against MC2 and ran both engines at 1,420 rpm for about 8 min (Figures 10 and 11). This caused an increase in velocity (to 2 fps) and in turbidity at the substratum-water interface (to slightly greater than 100 NTU). Turbidity at the surface changed from less than 10 NTU to about 30 NTU for a short period of time.

Summary

These short periods of elevated suspended sediments and water velocity caused by movement of the *Pleasant* when shuttling barges can be considered minor. In addition, they took place at the extreme upper reach of the mussel bed. Dense and diverse assemblages of mussels farther downriver should be completely unaffected by the *Pleasant*. These changes in turbidity are within the range of values typically found during high-water events in large rivers.

3 Biological Conditions

Mollusc Community

Twenty-three species of mussels were collected using qualitative methods at six sites in the mussel bed downriver of the William H. Zimmer Station (see Table 1 and Figure 12). The fauna was dominated by three species (*Q. p. pustulosa*, *A. p. plicata* (Say, 1817), and *P. cordatum*), which together comprised 61.5 percent of the assemblage. Ten species were common and each comprised 9 to 1 percent of the assemblage; ten species were uncommon and each comprised less than 1 percent of the assemblage. The three abundant species were found in more than 80 percent of the quadrats. Distribution of species abundance was even, with no evidence of a distinct dominant (Figure 12).

The relationship between cumulative individuals and cumulative species collected provides a measure of the difficulty of finding rare species. Figure 13, which includes all individuals collected qualitatively, illustrates that after approximately 400 individuals had been taken, a total of 18 species had been identified. After an additional 400 individuals were collected, five more species were found. A sample of 400 individuals was sufficient to obtain 78.6 percent of the species in this bed.

No specific trends were found with respect to relative species abundance versus river mile for the six qualitative samples (Table 2, Figure 14). Percentages of *Q. p. pustulosa*, *A. p. plicata*, and *P. cordatum* varied among sites but showed no pattern with respect to river mile. The percentage of *Quadrula metanevra* (Rafinesque, 1820) decreased moving downriver, and the percentage of *Megalonaias nervosa* (Rafinesque, 1820) was greater at the downriver sites. Frequency of occurrence of unionids collected in the qualitative samples is summarized in Table 3.

Total mussel density ranged from 23.2 to 52.4 individuals/sq m (Table 4 and Figure 15). Density of *C. fluminea* ranged from 472.0 to 828.0 individuals/sq m, approximately 10 times that of the Unionidae. Total biomass values of Unionidae and *C. fluminea* were similar at all sites except at RM 444.6. At this site, unionid density and biomass were substantially less than at other sites.

A total of 20 species were taken in the 40 quantitative samples (Figure 16 and Table 5). Total species richness was less in the quantitative samples because fewer individuals were taken (367) than in all qualitative samples (1,141) (Table 1). All four sites exhibited a fairly even distribution of species (Figure 17).

Species diversity ranged from 2.06 to 2.25, and evenness ranged from 0.76 to 0.83 at the four sites sampled quantitatively at the mussel bed (Table 5). No specific trends were found with respect to river mile. The number of organisms less than 30-mm total shell length provides a measure of recent recruitment and an index of the health of the mussel bed. The percentage of individuals (9.90 to 16.03) and species (35.29 to 40.00) less than 30-mm total shell length was similar at all four sites and showed no specific trend with respect to river mile (Table 5).

Frequency of occurrence of unionids collected using quantitative methods is shown in Table 6. *Quadrula pustulosa pustulosa* and *P. cordatum* were found in the majority of the quadrats (typically greater than 70 percent). Frequency of occurrence in qualitative (Table 1) and total quantitative samples (Table 6) was similar.

Size Demography

Corbicula fluminea

At all four sites surveyed, *C. fluminea* had three clearly discernible cohorts that were centered at 10-, 15-, and 30-mm shell length (Figures 18a-d). Cohorts centered at 10- and 30-mm shell length were approximately four times more abundant than the one centered at 15-mm shell length. *Corbicula fluminea* typically has spring and fall peaks in reproduction and recruitment, and most individuals survive 12 to 24 months. Presumably, the cohorts at 10, 15, and 30 mm correspond to spring 1991, fall 1990, and spring 1990 recruitment classes, respectively.

The size demography of *C. fluminea* was identical at sites 3 and 4, where the spring cohorts were equally abundant and more prevalent than the fall cohort. At RM 444.2-d, the spring 1990 cohort was more abundant than both of the younger cohorts. Only the population at RM 444.2-u displayed a spring 1991 cohort that was more abundant than the spring 1990 cohort. This relatively low abundance of the oldest cohort at RM 444.2-u could reflect lower substratum stability and reduced survival of *C. fluminea* in its second year of life.

Pleurobema cordatum

This abundant unionid showed evidence of generally strong recruitment in all but the most recent years (Figure 19). The approximately equal abundance of mussels from 40 to 90 mm in shell length indicates sustained recruitment over several years. Although the sample size was insufficient to allow detailed analysis, cohorts were evident at approximately 42, 54, 66, 72, 78, and 84 mm in length, which probably represent six consecutive year classes from the late to early 1980s. Three mussels were collected with shell lengths of 28 to 34 mm; these probably represent 1988 or 1989 recruitment. More recent recruits were not found.

Obliquaria reflexa

This population appeared to consist of four to five cohorts. The smallest cohort was abundant and centered at 32-mm shell length (Figure 20). The next larger cohort was equally abundant and centered at 40 mm. The next equally abundant cohort was centered at 54 mm, but a cohort of low relative abundance was barely evident at 48 mm. The broad shoulder on the upper end of the size distribution of the 54-mm cohort (i.e., individuals ranging from 56 to 64 mm in length) probably represents a fifth cohort. The lack of mussels less than 30 mm in length indicates, as for *P. cordatum*, that very recent recruitment has not been strong. The 32-mm cohort of *O. reflexa* probably represents 1989 or 1988 recruitment.

Quadrula pustulosa pustulosa

This moderately sized, thick-shelled unionid exhibited fairly uniform recruitment each year (Figure 21). Size classes between 26 and 30 mm and between 36 and 40 mm were slightly reduced, indicating only moderate recruitment periods.

Quadrula metanevra, *Amblema plicata plicata*, and *Ellipsaria lineolata* (Rafinesque, 1820)

Detailed analysis of these moderately abundant unionid populations was not possible (Figures 22-24). However, all three populations followed the general patterns of both *P. cordatum* and *O. reflexa* in that individuals of most sizes were present, representing sustained recruitment in most years. Some of the smallest unionids found in this survey were *A. p. plicata* (minimum length of 14 mm), indicating that at least some recruitment of this species occurred as recently as 1990.

Physical Condition

Relationships between shell length and shell mass, tissue dry mass, or total mass provide an index of the overall health of an individual. For freshwater mussels, these are similar to the condition indices used as a measure of robustness by fisheries biologists. The relationship of total shell length to these three morphometric indices for four species of mussels collected in 1991 is illustrated in Figures 25-28. The data were separated by river mile (sites that were located progressively farther downriver from the facility) to enable a determination of environmental impacts of barge traffic.

No substantial differences in any of these parameters were noted with respect to river mile. Future measurement of these indices, after the facility has been in operation for several more years, will provide a means of evaluating the overall impacts of barge operation at this facility.

Growth Studies

Growth rates of four dominant species (*A. p. plicata*, *O. reflexa*, *P. cordatum*, and *Q. p. pustulosa*) were evaluated for a site immediately downriver of MC3 (RM 444.2), a second site located downriver (RM 444.4), and a reference site located farther downriver (RM 444.6) (Figures 29 and 30). Growth rates for *A. p. plicata* were similar at all sites, and growth rates for small individuals (less than 40-mm total shell length) were similar for *O. reflexa*. Growth rates for *P. cordatum* were substantially less at RM 444.4 than at the sites immediately upriver and downriver (Figure 30). Growth rates for *Q. p. pustulosa* were slightly greater at RM 444.6 than the two other sites located upriver (Figure 30).

It is unlikely that these variations in growth reflect anything more than variability among sites. Future studies, to be conducted after the facility has operated for several years, will be used to more fully assess growth rates at these sites.

4 Discussion

Stansbery and Cooney (1985) collected mussels in 1984 at this bed with a brail, by hand along the shore, and with a diver. Collections by their diver should be considered semiquantitative; although premeasured areas of river bottom were searched, total substratum samples were not obtained. As reported, Stansbery and Cooney (1985) collected a grand total of 2,432 individuals and 29 species (Table 7). If results from our qualitative and quantitative work in 1989 and 1990 are combined (Miller and Payne 1991), we took 2,673 individuals and identified 27 species. We found a single *Lampsilis abrupta* (Say, 1821) not on their list, and Stansbery and Cooney (1985) took three species along the shore that we did not collect--*Potamilus ohioensis* (Rafinesque, 1820), *Toxolasma parvus* (Barnes, 1823), and *Anodonta suborbiculata* (Say, 1831).

Twenty-six species were common to both surveys. Although sampling techniques differed, estimates of species richness, species diversity, evenness, and community composition were similar (Table 7). Based on an examination of these data, it appears that biotic conditions are stable at this bed.

A comparison of species diversity and evenness for individual qualitative samples (and not the total summary of all individuals collected as in Table 7) illustrates that, for the years 1989, 1990, and 1991, these parameters remained essentially unchanged (Figure 31, Tables 2 and 8). In addition, the total number of species collected at each site using qualitative methods (Figure 32, Tables 2 and 8) has not changed during this study. A comparison of density data from this survey (Figure 15) with those collected in 1989 and 1990 (Table 9) indicates that these data are variable; however, no specific trends were detected.

The number of individuals and species less than 30-mm total shell length provides an estimate of the overall health of the mussel bed. A negative trend with respect to percentage of individuals less than 30 mm was not discernible (Figure 33). Although the percentage of species less than 30-mm total shell length was more variable than the number of individuals, this parameter showed no specific trend through time. Periods of poor recruitment for dominant species should not necessarily be considered an indication of poor conditions for unionids. Many factors determine whether mussels successfully

recruit in large numbers each year. In addition, consistent annual recruitment is probably not a requisite for success in a long-lived species.

Physical changes brought about by operation of the workboat *Pleasant* can be considered minor, and will likely have little or no measurable effect on the mussel populations located downriver. It should be noted that all of our physical studies were conducted at the extreme upriver portion of the mussel bed. Effects of the *Pleasant* farther downriver, at the center portion of the bed, would probably not be detectable.

The continued use of inland waterways to transport bulk commodities (Dietz et al. 1983) has caused planners and biologists in government agencies to express concern over the possible negative effects of commercial traffic on freshwater mussels (Rasmussen 1983). Rather than rely on speculation or questionable predictive methods, quantitative and qualitative techniques should be used to obtain data on mussel density, relative species abundance, community composition, and population demography. Estimates of total density, measures of recruitment, and adequate characterization of population demography require quantitative, total substratum samples (Miller and Payne 1988). However, qualitative methods can be used to search for endangered species and to evaluate community characteristics.

Based on our surveys, no measurable changes have occurred in growth rates, diversity, or density of molluscs in the last 3 years. It does not appear that any measurable changes have taken place in the molluscan community since the survey conducted by Stansbery and Cooney (1985).

The results of future studies at this mussel bed, to be conducted after the station has operated for several years, will provide information that could be used to assist with the evaluation of the effects of coal deliveries by barge on the freshwater molluscs at this site. Results will have to be interpreted cautiously. It is likely that, through time, the water and habitat quality of the Ohio River will be altered by the cumulative effects of multiple water resource projects located upriver. Predicting and explaining environmental effects is rarely unambiguous. However, the availability of these quantitative data will provide a basis for informed decisions.

References

- Bickel, D. (1966). "Ecology of *Corbicula manilensis* Philippi in the Ohio River at Louisville, Kentucky," *Sterkiana* 23,19-24.
- Dames and Moore. (1980). "Mussel survey findings in the vicinity of the William H. Zimmer Nuclear Power Station," prepared for Cincinnati Gas & Electric Company, Cincinnati, OH.
- Dietz, A. R., Harrison, R. W., Olson, H. E., Grier, D., and Simpkins, C. (1983). "National waterways study--A framework for decision making--Final Report," Report NWS-83-1, U.S. Army Engineer Institute for Water Resources, Water Resources Support Center, Fort Belvoir, VA.
- Environmental Science and Engineering, Inc. (1988). "Report on the monitoring study of relocated mussels near Ripley, Ohio," ESE No. 87-856, prepared for Mussel Mitigation Trust Fund Committee, Columbus, OH.
- Green, R. H. (1979). *Sampling design and statistical methods for environmental biologists*. John Wiley and Sons, New York.
- Hughes, R. G. (1986). "Theories and models of species abundance," *American Naturalist* 128,879-899.
- Hurlbert, S. H. (1984). "Pseudoreplication and the design of ecological field experiments," *Ecological Monographs* 54,187-211.
- Isom, B. G., and Gooch, C. (1986). "Rationale and sampling design for freshwater mussels, Unionidae, in streams, large rivers, impoundments, and lakes." *Rationale for sampling and interpretation of ecological data in the assessment of freshwater ecosystems*. ASTM STP 894. B. G. Isom, ed. American Society for Testing and Materials, Philadelphia, PA. 46-59.
- Keup, L., Horning, W. B., and Ingram, W. M. (1963). "Extension of range of Asiatic clam to Cincinnati reach of the Ohio River," *Nautilus* 77,18-21.

- Kovalak, W. P., Dennis, S. D., and Bates, J. M. (1986). "Sampling effort required to find rare species of freshwater mussels." *Rationale for sampling and interpretation of ecological data in the assessment of freshwater ecosystems*. ASTM STP 894. B. G. Isom, ed. American Society for Testing and Materials, Philadelphia, PA. 34-45.
- McNaughton, S. J., and Wolf, L. L. (1973). *General ecology*. Holt, Rinehart and Winston, New York.
- Miller, A. C., and Payne, B. S. (1988). "The need for quantitative sampling to characterize size demography and density of freshwater mussel communities," *Bulletin of the American Malacological Union* 6,49-54.
- _____. (1991). "Phase II studies: Impacts of commercial navigation traffic on freshwater mussels at the W. H. Zimmer Station, 1989-90 baseline studies," Technical Report EL-91-12, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Neff, S. E., Pearson, W. D., and G. C. Holdren. (1981). "Aquatic and terrestrial communities in the lower Ohio River (RM 930-981)," prepared for U.S. Army Engineer District, Louisville, Louisville, KY.
- Rasmussen, J. L. (1983). "A summary of known navigation effects and a priority list of data gaps for the biological effects of navigation on the upper Mississippi River," prepared by U.S. Fish and Wildlife Service for U.S. Army Engineer District, Rock Island, Rock Island, IL.
- Rhoads, S. N. (1899). "On a recent collection of Pennsylvania mollusks from the Ohio River system below Pittsburgh," *The Nautilus* 12,133-137.
- Shannon, C. E., and Weaver, W. (1949). *The mathematical theory of communication*. University of Illinois Press, Urbana, IL.
- Stansbery, D. H., and J. D. Cooney. (1985). "Survey of the unionid mollusks of the Ohio River in the vicinity of the William H. Zimmer Station (Ohio River Miles 442.6 to 445.6)," prepared for Cincinnati Gas and Electric Company, Columbus and Southern Electric Company, and Dayton Power and Light Company.
- Taylor, R. W. (1980). "A survey of the freshwater mussels of the Ohio River from Greenup Locks and Dam to Pittsburgh, PA," U.S. Army Engineer District, Huntington, Huntington, WV.
- _____. (1989). "Changes in freshwater mussel populations of the Ohio River: 1,000 BP to recent times," *The Ohio Journal of Science* 89,188-191.

- Tolin, W. A., Schmidt, J., and Zeto, M. (1987). "A new location for the Federally-listed endangered unionid *Lampsilis abrupta* (Say, 1821) (= *Lampsilis crbiculata* (Hildreth, 1828)), the pink mucket, in the upper Ohio River bordering West Virginia," *Malacology Data Net* 2,18.
- Turgeon, D. D., Bogan, A. E., Coan, E. V., Emerson, W. K., Lyons, W. G., Pratt, W. L., Roper, C. F. E., Scheltema, A., Thompson F. G., and Williams, J. D. (1988). "Common and scientific names of aquatic invertebrates from the United States and Canada: Mollusks," Committee on Scientific and Vernacular Names of Mollusks of the Council of Systematic Malacologists, American Malacological Union, Bethesda, MD.
- U.S. Fish and Wildlife Service. (1991). "Endangered and threatened wildlife and plants," *Federal Register* (15 Jul). 50 CFR 17.11 & 17.12.
- Way, C. M., Miller, A. C., and Payne, B. S. (1990). "The influence of physical factors on the distribution and abundance of freshwater mussels (Bivalvia: Unionidae) in the lower Tennessee River," *The Nautilus* 103,96-98.
- Williams, J. C. (1969). "Mussel fishery investigations, Tennessee, Ohio and Green Rivers," Project Completion Report for Investigations Projects Conducted under the Commercial Fisheries Research and Development Act of 1964, U.S. Fish and Wildlife Service and Kentucky Department of Fish and Wildlife Resources, Frankfort, KY.
- Williams, J. C., and Schuster, G. A. (1982). "Freshwater mussel investigations in the Ohio River Mile 317.0 to Mile 981.0," prepared for Department of Fish and Wildlife Resources, Division of Fisheries, Frankfort, KY.

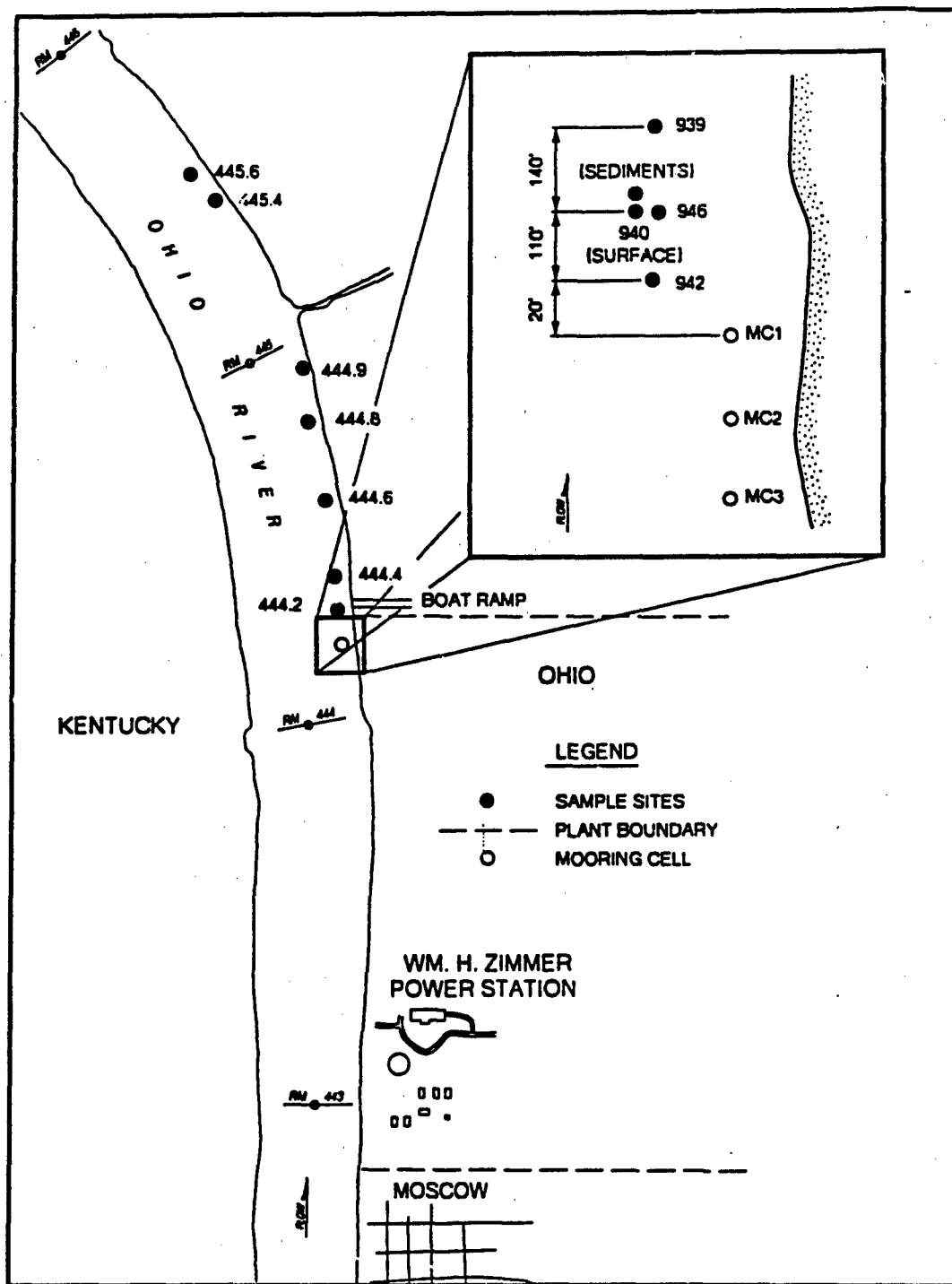


Figure 1. Map of study area. Inset shows placement of sensors for velocity tests

Ohio River Mile 444.2, 85 ft RDB
7 August 1991 - Test 6

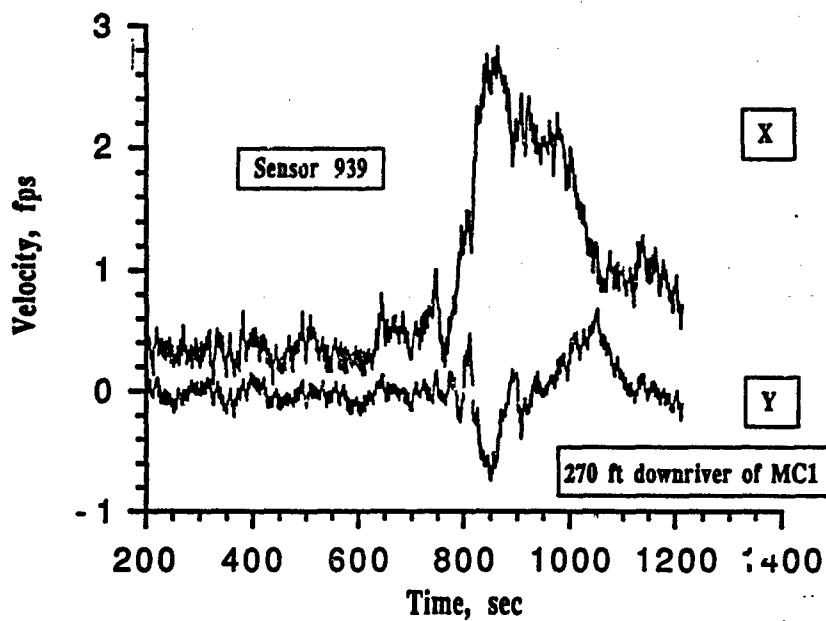
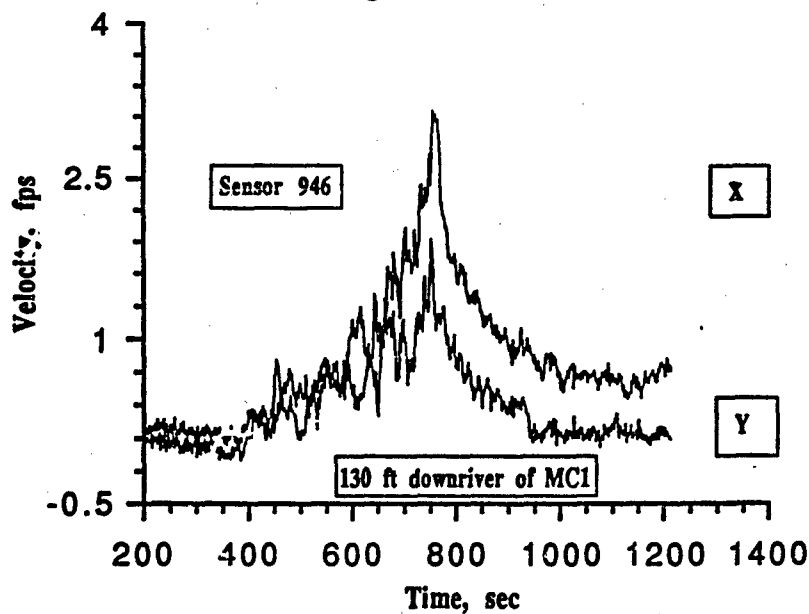


Figure 2. Individual components of water velocity, Sensors 946 and 939, for Test 6

Ohio River Mile 444.2, 85 ft RDB
7 August 1991 - Test 6

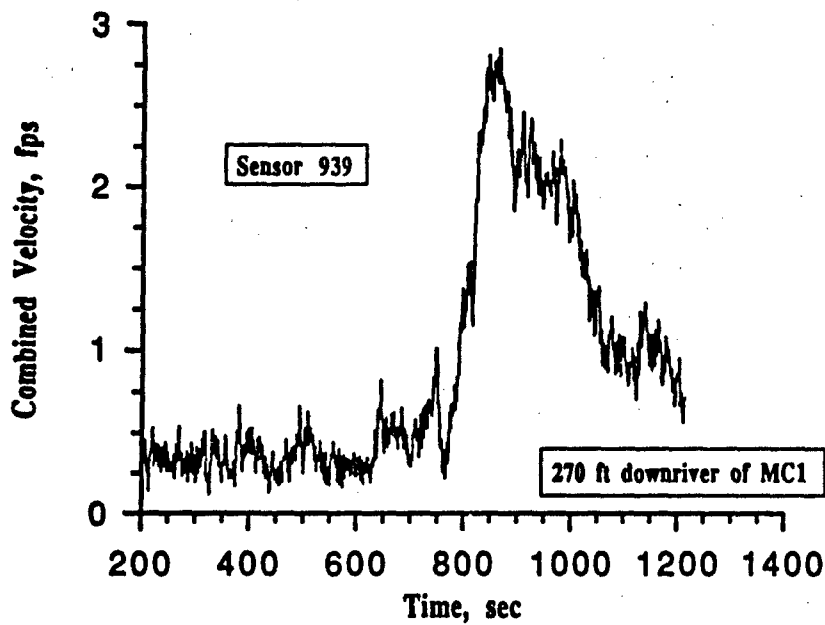
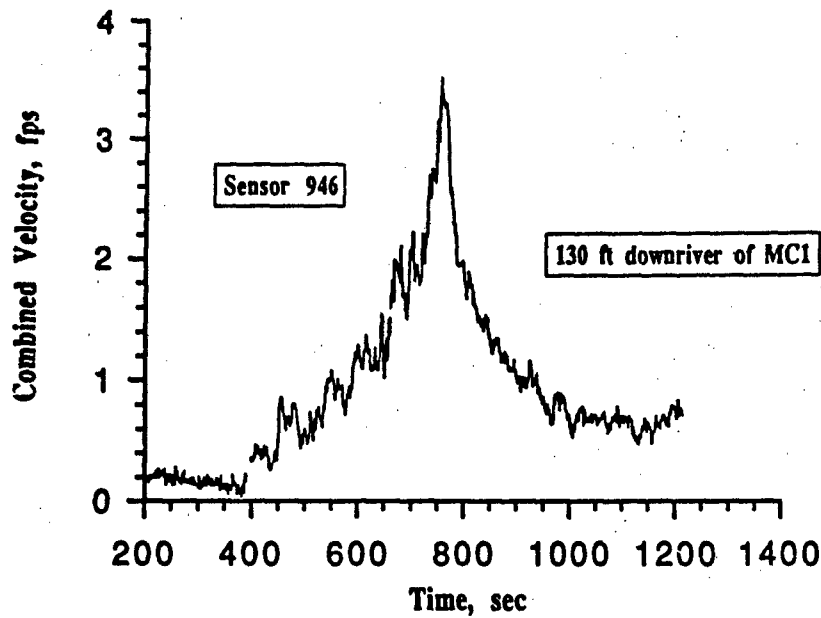


Figure 3. Combined or net velocity for Sensors 946 and 939, Test 6

Ohio River Mile 444.2, 85 ft RDB
7 August 1991 - Test 6

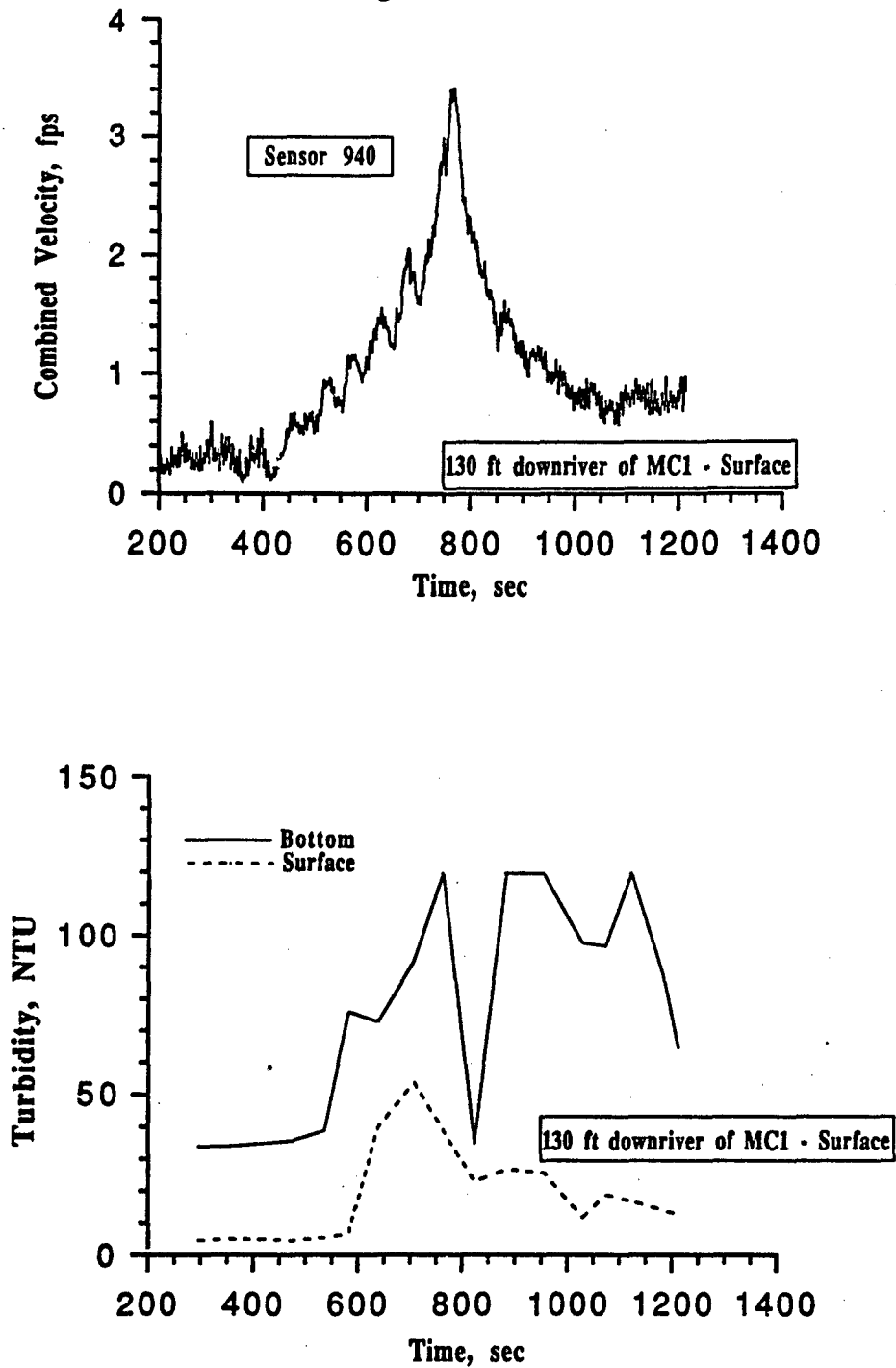


Figure 4. Combined velocity and changes in turbidity for Sensor 940, Test 6

Ohio River Mile 444.2, 85 ft RDB
7 August 1991 - Test 7

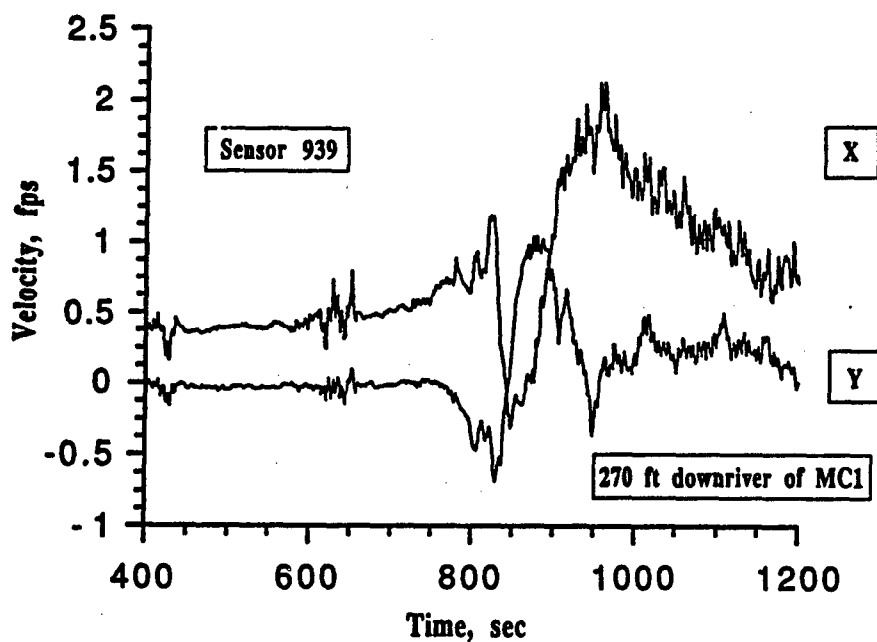
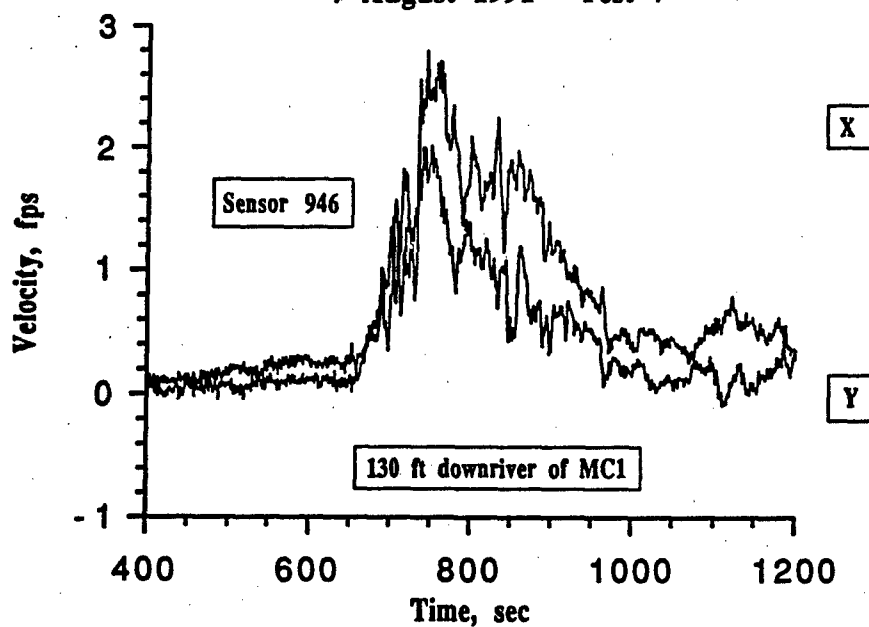


Figure 5. Individual components of water velocity, Sensors 946 and 939, Test 7

Ohio River Mile 444.2, 85 ft RDB
7 August 1991 - Test 7

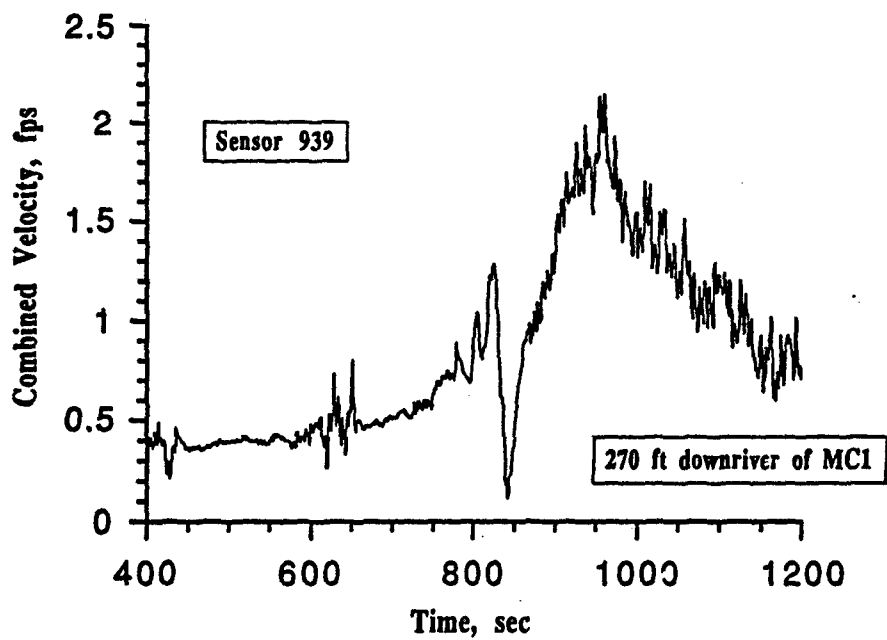
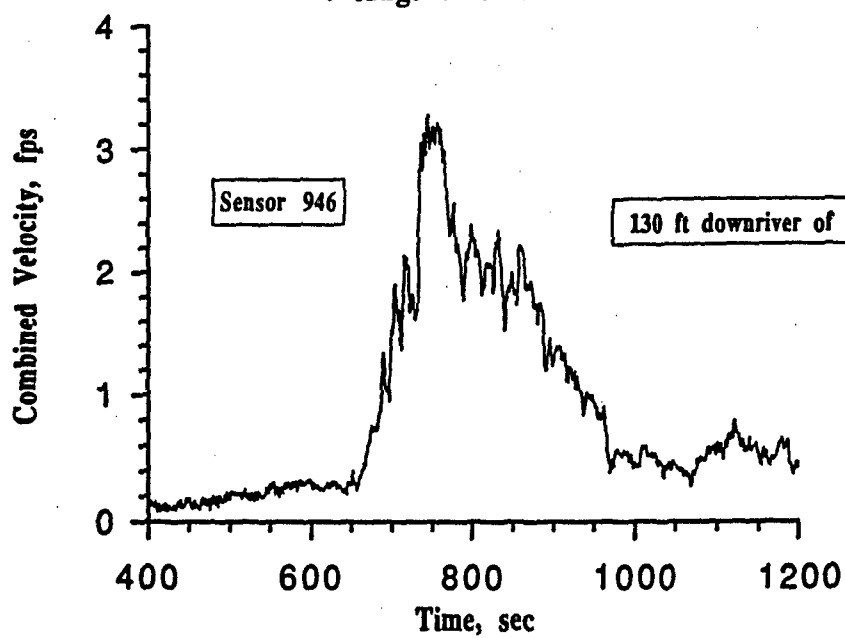


Figure 6. Combined or net velocity for Sensors 946 and 939, Test 7

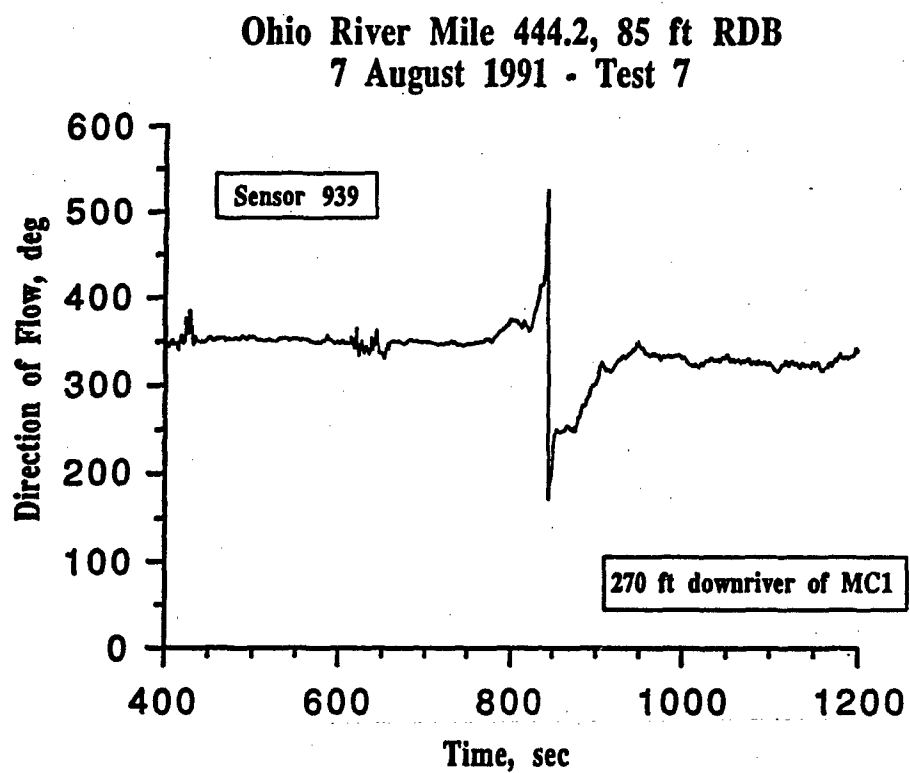


Figure 7. Change in direction of flow for Sensor 939, Test 7

Ohio River Mile 444.2, 85 ft RDB
7 August 1991 - Test 7

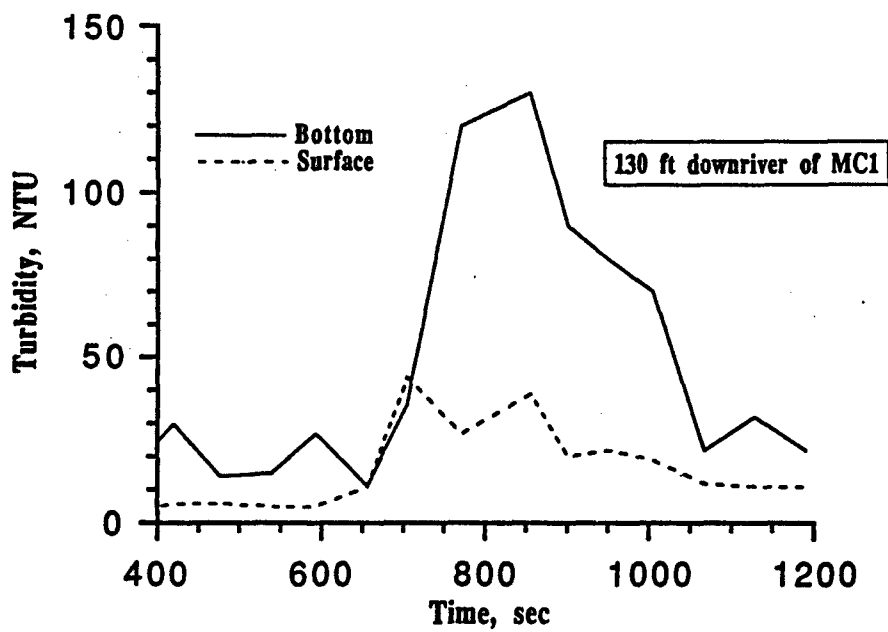
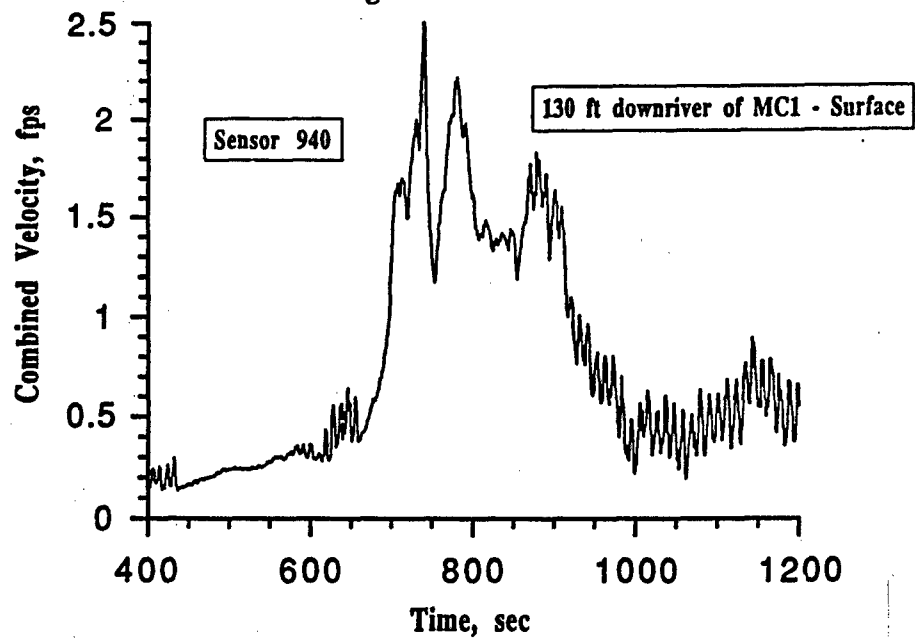


Figure 8. Combined velocity and changes in turbidity for Sensor 940, Test 7

Ohio River Mile 444.2, 85 ft RDB
7 August 1991 - Test 9

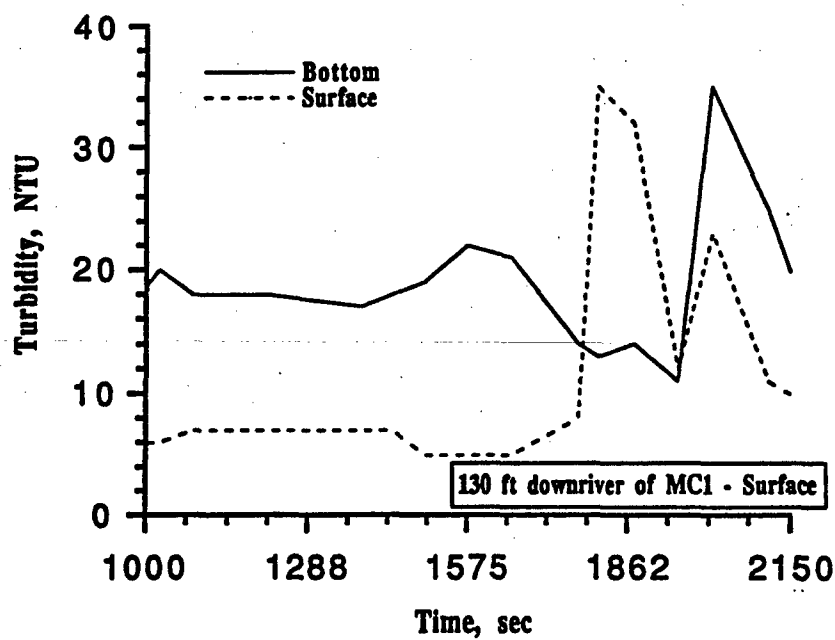
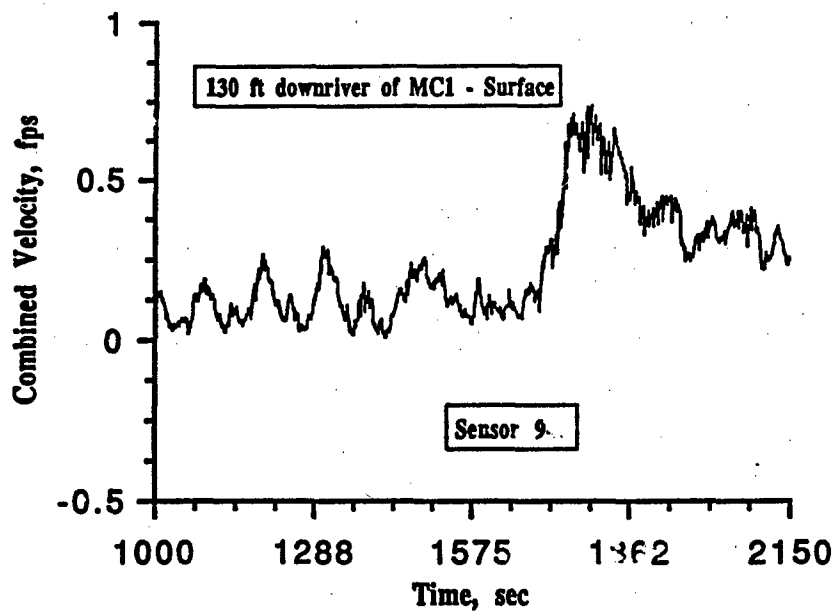


Figure 9. Combined or net velocity and changes in turbidity for Sensor 940, Test 9

Ohio River Mile 444.2, 85 ft RDB
7 August 1991 - Test 11

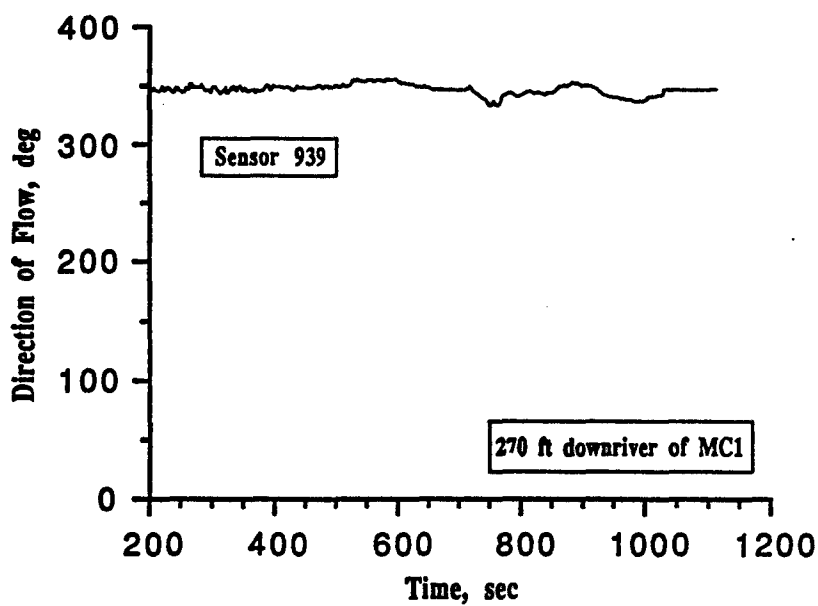
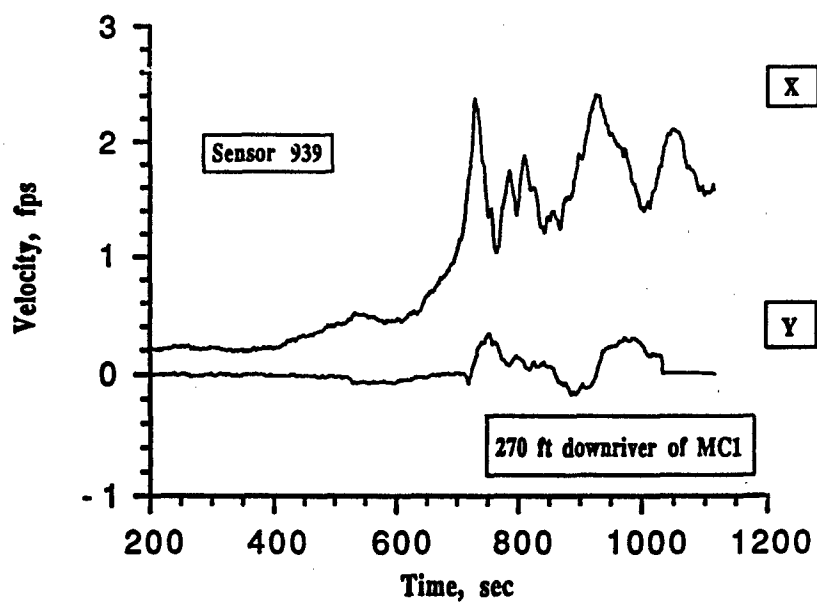


Figure 10. Individual components of velocity and direction of flow for Sensor 939, Test 11

Ohio River Mile 444.2, 85 ft RDB
7 August 1991 - Test 11

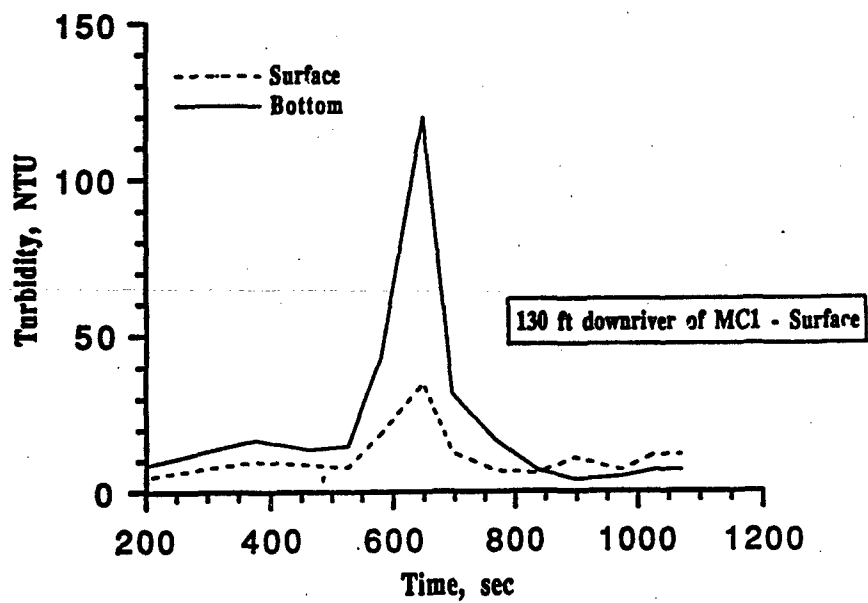
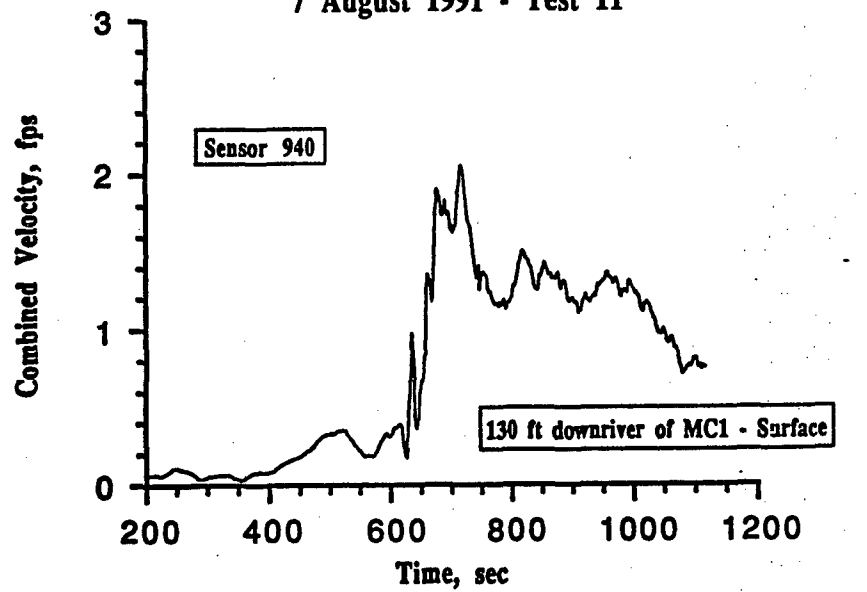


Figure 11. Combined or net velocity and changes in turbidity for Sensor 940, Test 11

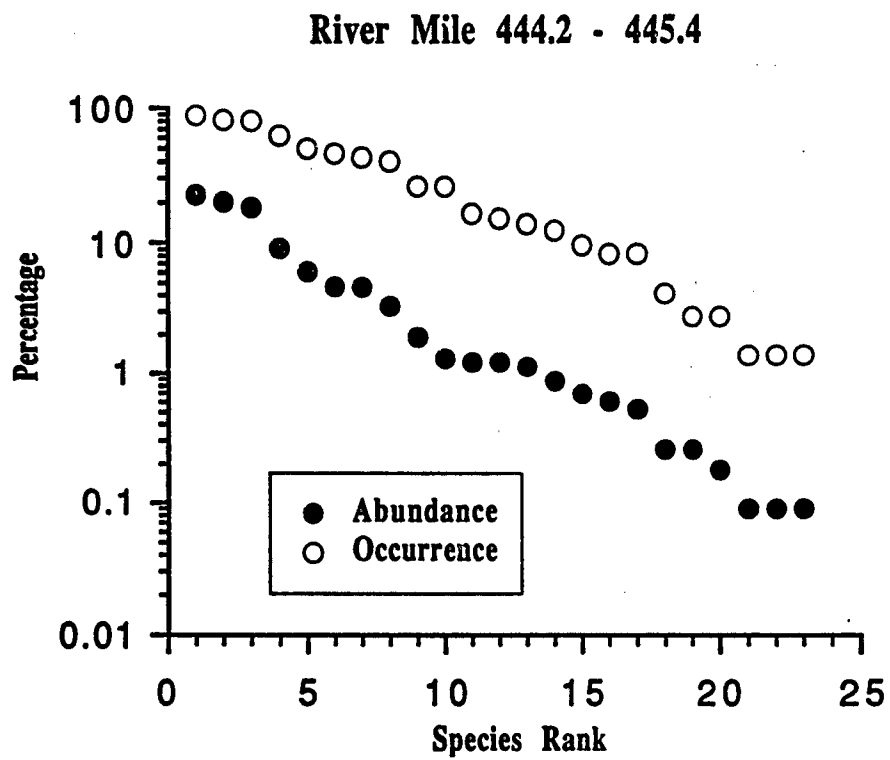


Figure 12. Relative species abundance and frequency of occurrence for freshwater mussels collected in six qualitative samples, 1991

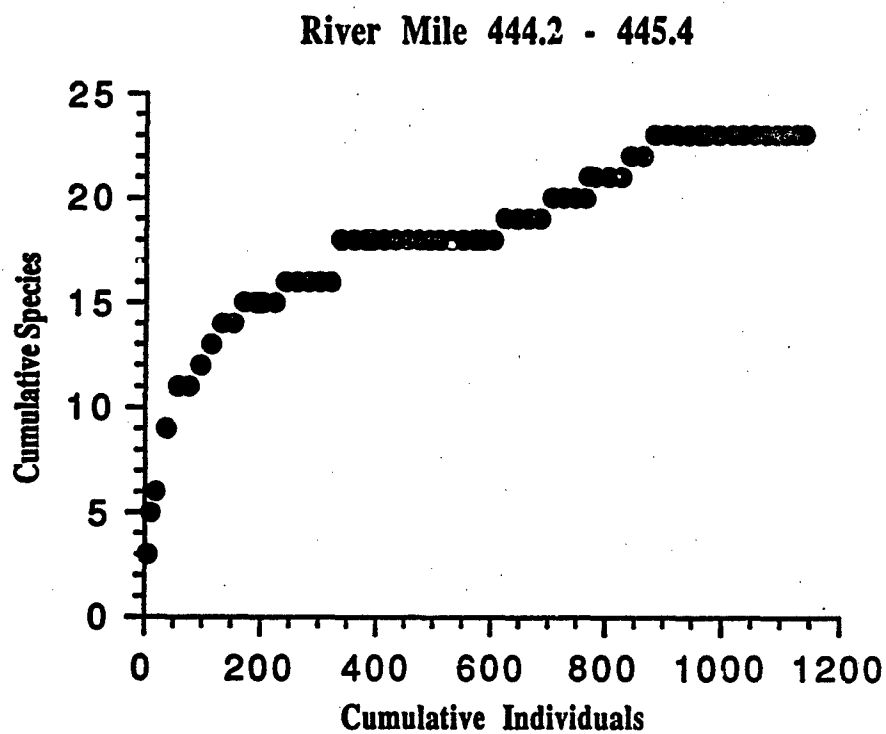
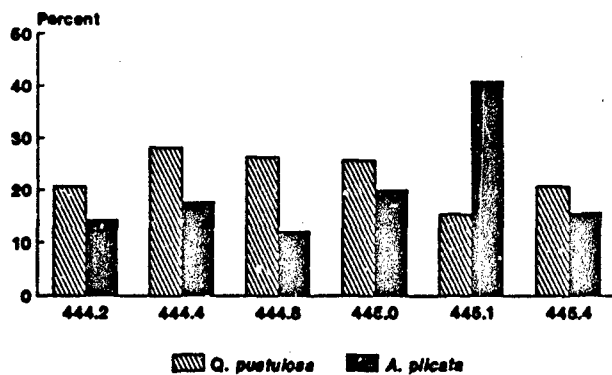
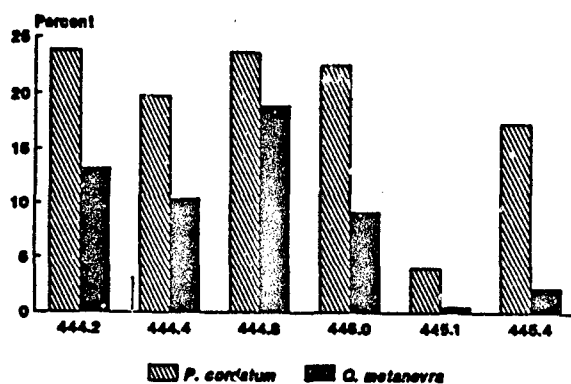


Figure 13. Relationship between cumulative species and cumulative individuals, based on six qualitative samples, 1991

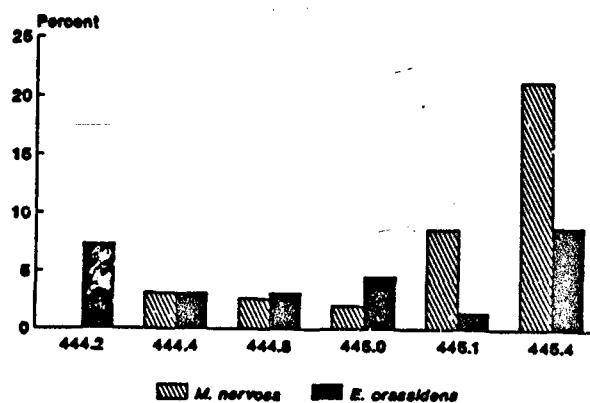
Zimmer Power Station, 1991 Qualitative Samples



zm91-10



zm91-11



zm91-12

Figure 14. Percent abundance of six species of freshwater molluscs collected at six sites, qualitative samples, 1991

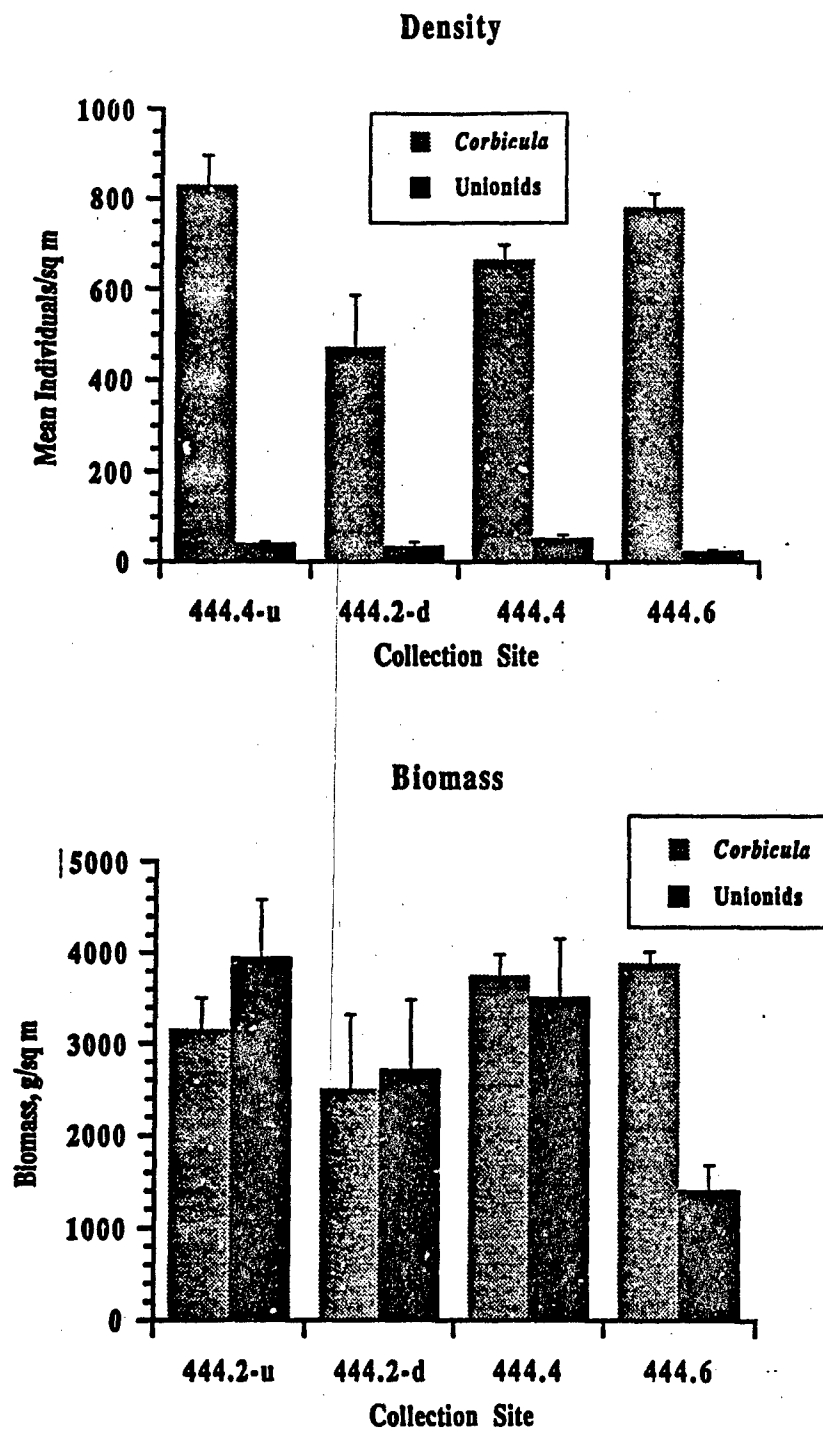


Figure 15. Mean total density and mean total biomass, 1991

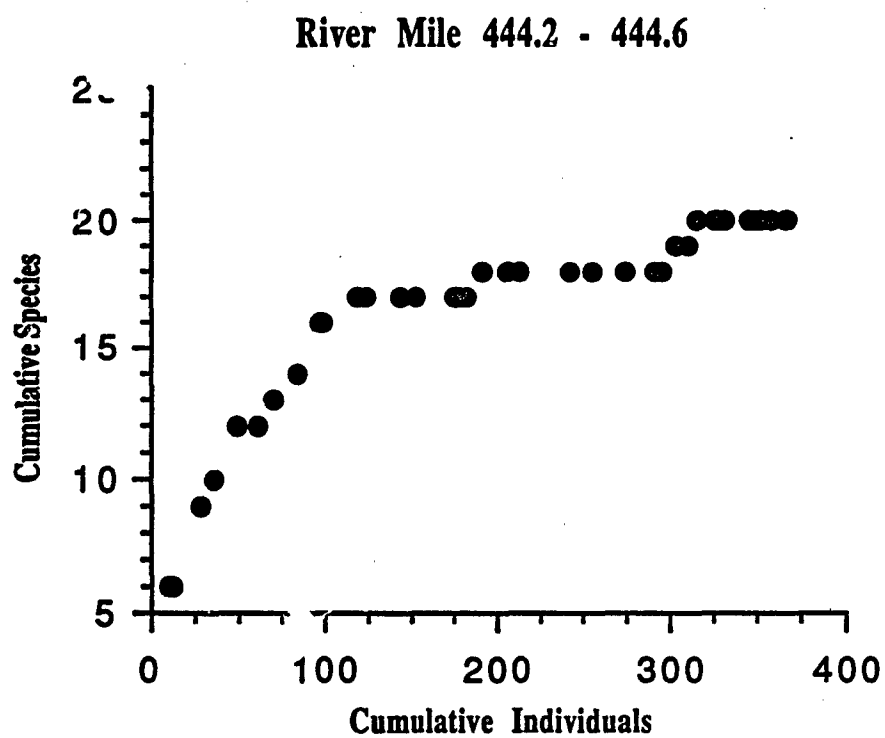


Figure 16. Relationship between cumulative species and cumulative individuals, based on four quantitative samples, 1991

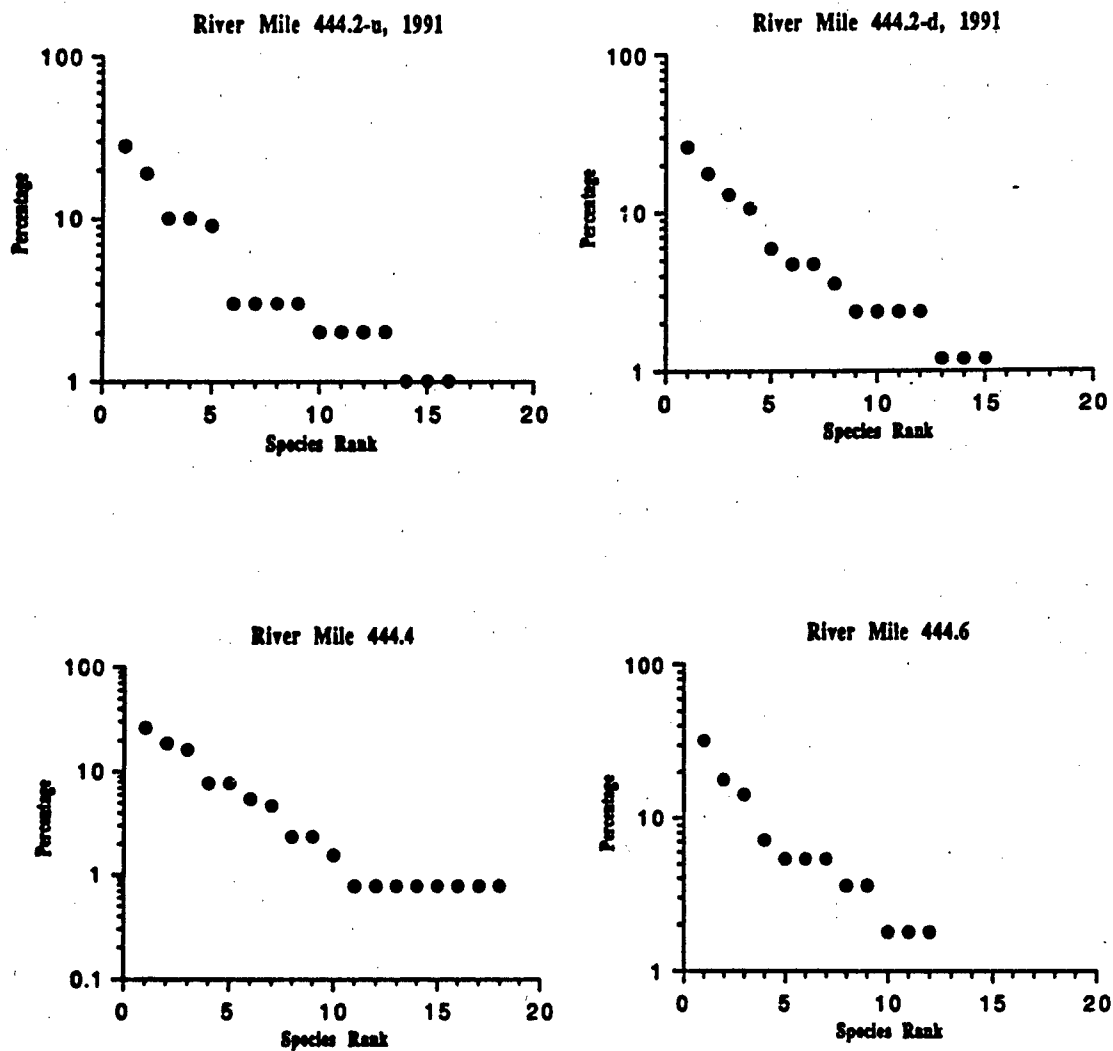
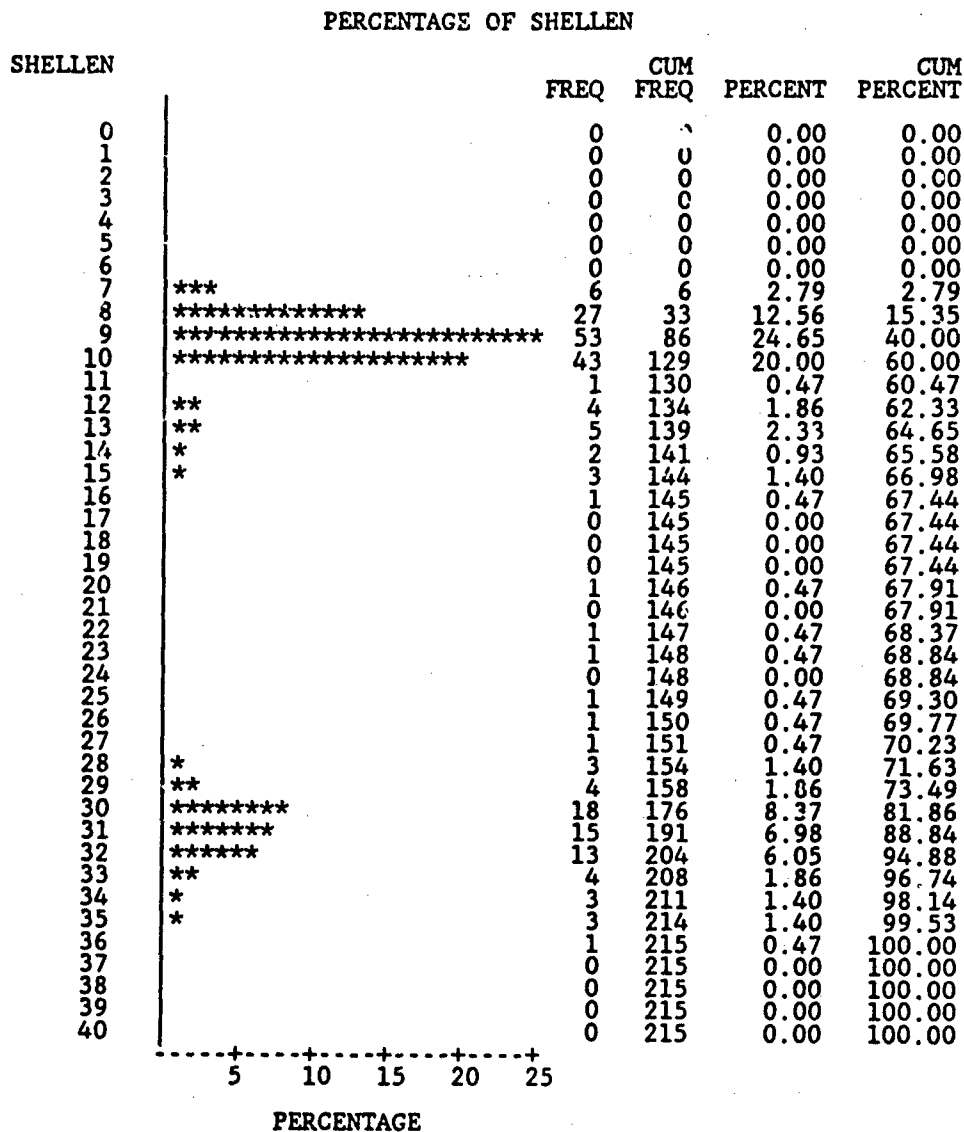


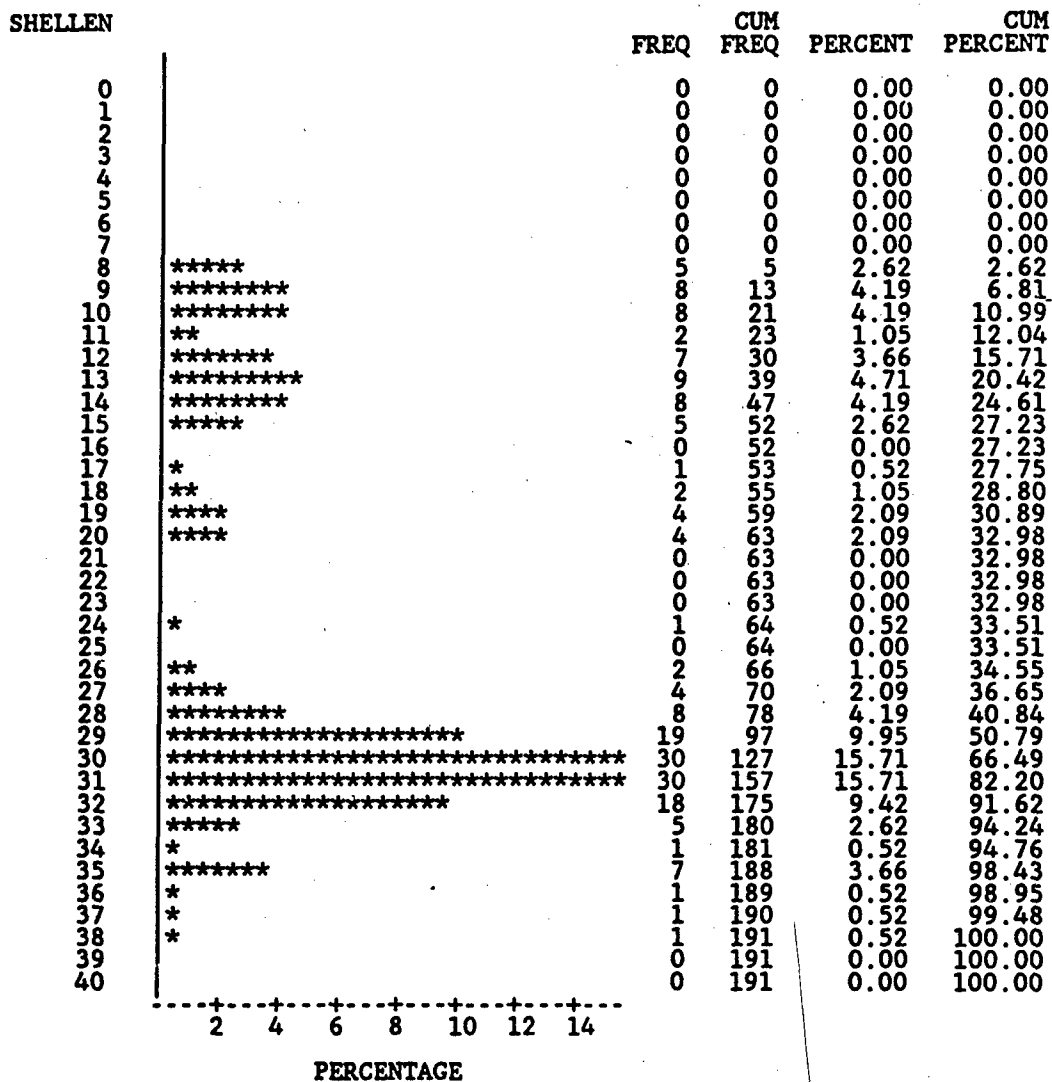
Figure 17. Relationship between percent abundance and species rank for four sites sampled quantitatively, 1991



a. RM 444.2-u

Figure 18. Length-frequency histograms for *Corbicula fluminea* collected at four sites, 1991 (Sheet 1 of 4)

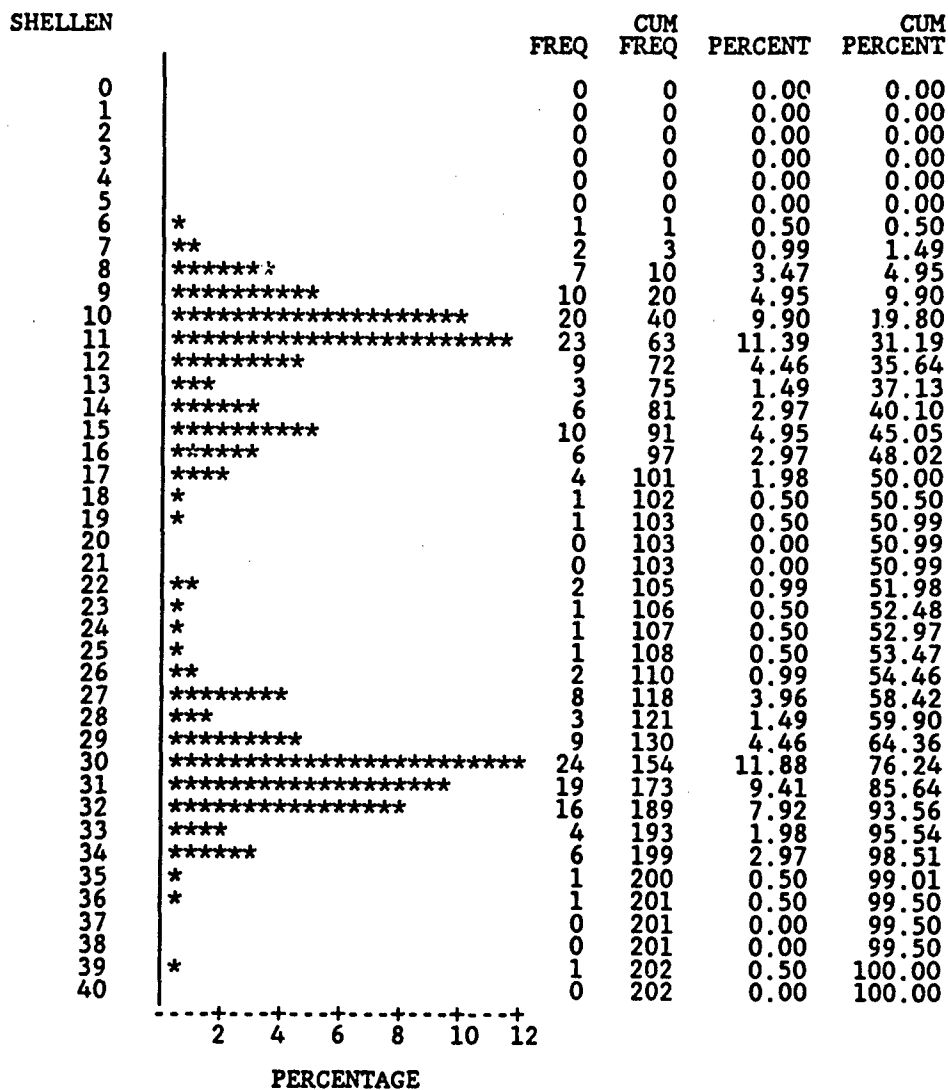
PERCENTAGE OF SHELLS



b. RM 444.2-d

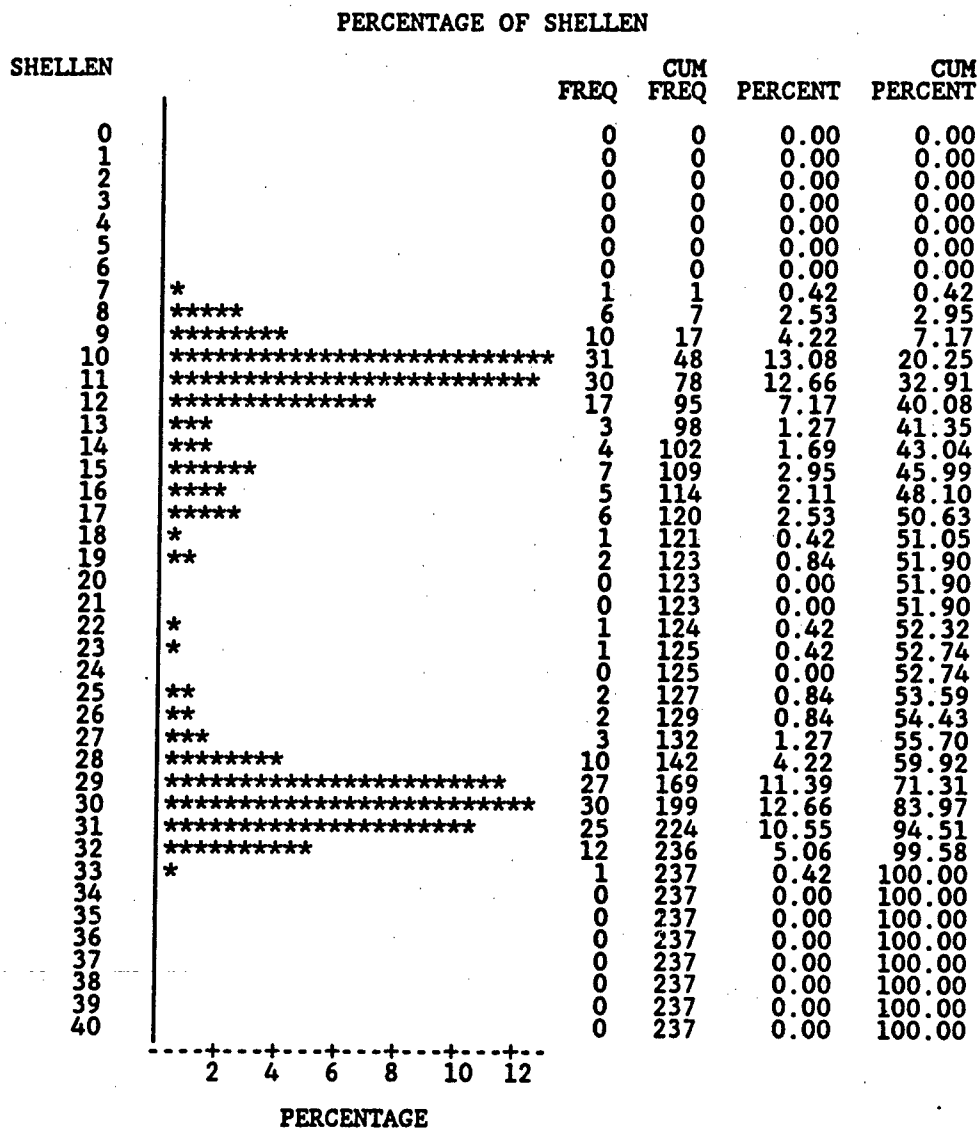
Figure 18. (Sheet 2 of 4)

PERCENTAGE OF SHELLS



c. RM 444.2

Figure 18. (Sheet 3 of 4)



d. RM 444.6

Figure 18. (Sheet 4 of 4)

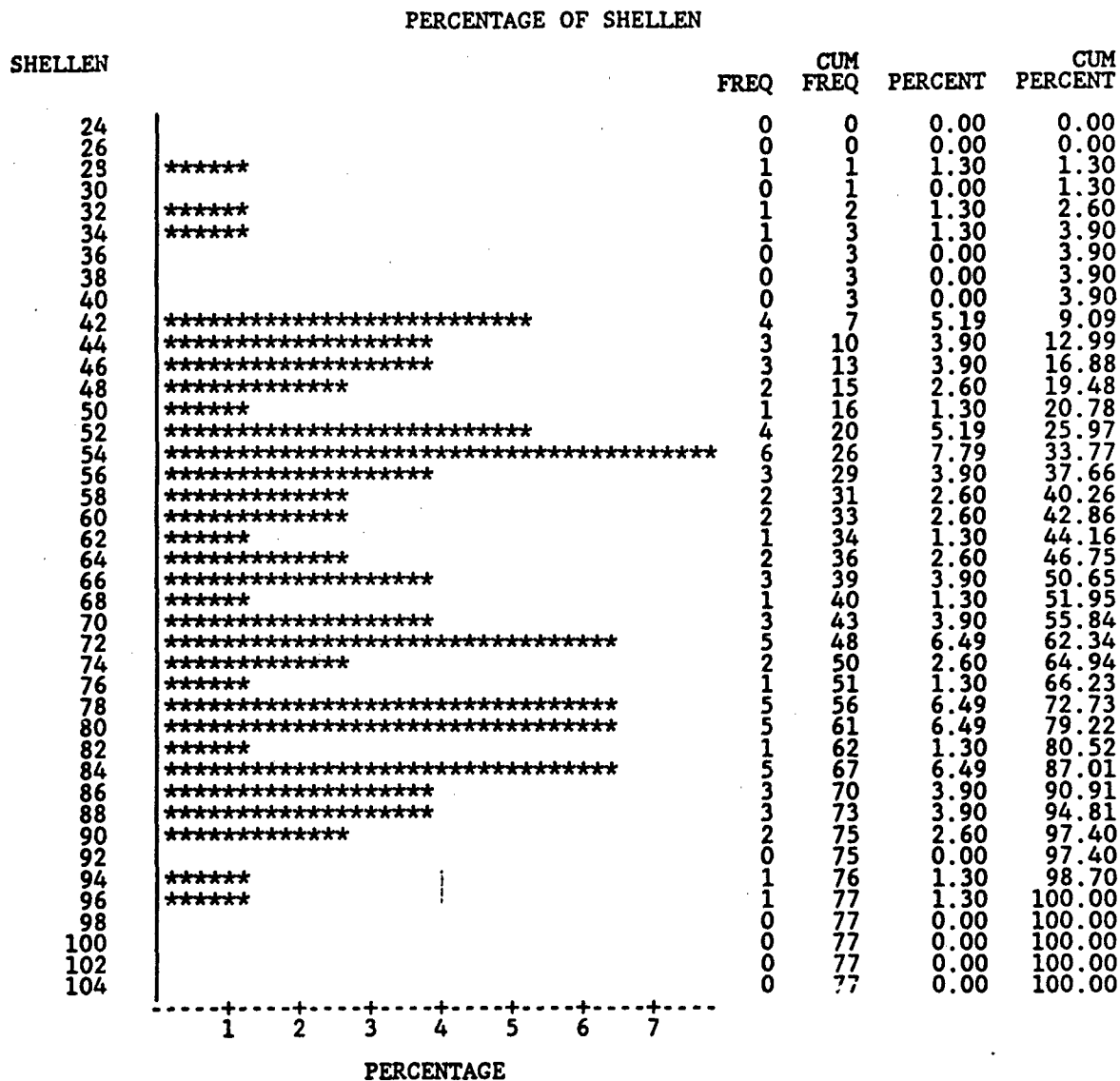


Figure 19. Length-frequency histogram for *Pleurobema cordatum*, all four sites combined, 1991

| SHELLEN | FREQ | CUM FREQ | PERCENT | CUM PERCENT |
|---------|------|----------|---------|-------------|
| 16 | 0 | 0 | 0.00 | 0.00 |
| 18 | 0 | 0 | 0.00 | 0.00 |
| 20 | 0 | 0 | 0.00 | 0.00 |
| 22 | 0 | 0 | 0.00 | 0.00 |
| 24 | 0 | 0 | 0.00 | 0.00 |
| 26 | 0 | 0 | 0.00 | 0.00 |
| 28 | 1 | 1 | 2.00 | 2.00 |
| 30 | 3 | 4 | 6.00 | 8.00 |
| 32 | 5 | 9 | 10.00 | 18.00 |
| 34 | 4 | 13 | 8.00 | 26.00 |
| 36 | 1 | 14 | 2.00 | 28.00 |
| 38 | 3 | 17 | 6.00 | 34.00 |
| 40 | 6 | 23 | 12.00 | 46.00 |
| 42 | 3 | 26 | 6.00 | 52.00 |
| 44 | 1 | 27 | 2.00 | 54.00 |
| 46 | 0 | 27 | 0.00 | 54.00 |
| 48 | 2 | 29 | 4.00 | 58.00 |
| 50 | 1 | 30 | 2.00 | 60.00 |
| 52 | 5 | 35 | 10.00 | 70.00 |
| 54 | 7 | 42 | 14.00 | 84.00 |
| 56 | 2 | 44 | 4.00 | 88.00 |
| 58 | 2 | 46 | 4.00 | 92.00 |
| 60 | 2 | 48 | 4.00 | 96.00 |
| 62 | 1 | 49 | 2.00 | 98.00 |
| 64 | 1 | 50 | 2.00 | 100.00 |
| 66 | 0 | 50 | 0.00 | 100.00 |
| 68 | 0 | 50 | 0.00 | 100.00 |
| 70 | 0 | 50 | 0.00 | 100.00 |

-----+-----+-----+-----+-----+-----+-----+-----
 2 4 6 8 10 12 14
 PERCENTAGE

Figure 20. Length-frequency histogram for *Obliquaria reflexa*, all four sites combined, 1991

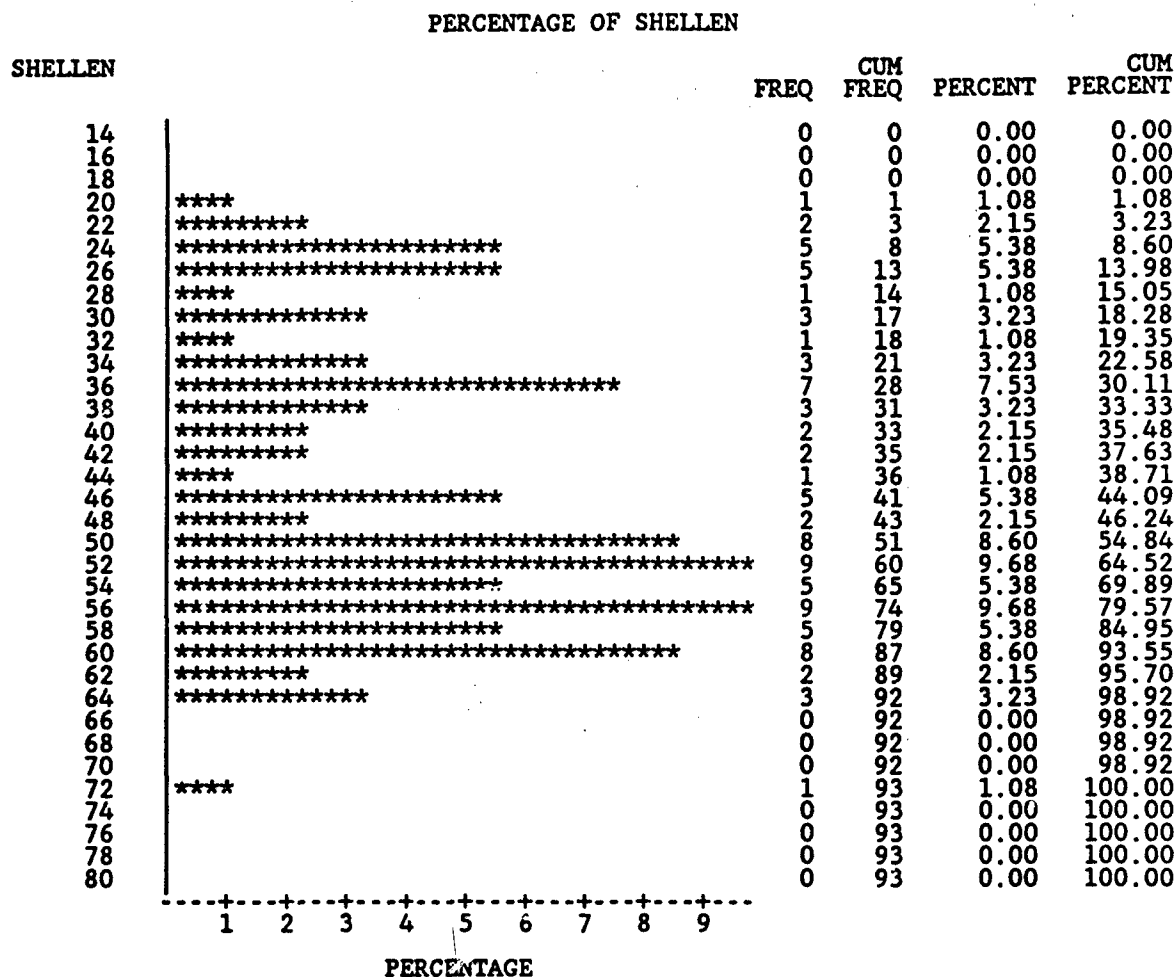


Figure 21. Length-frequency histogram for *Quadrula pustulosa*, all four sites combined, 1991

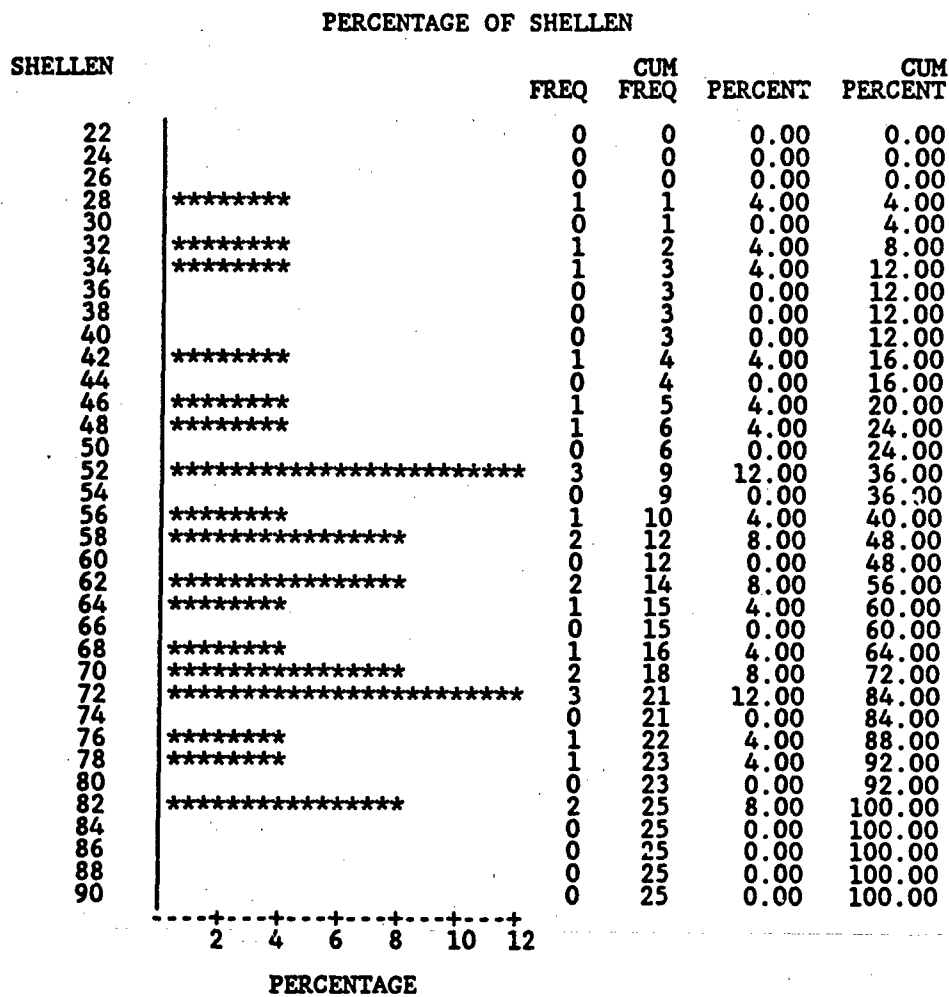


Figure 22. Length-frequency histogram for *Quadrula metanevra*, all four sites combined, 1991

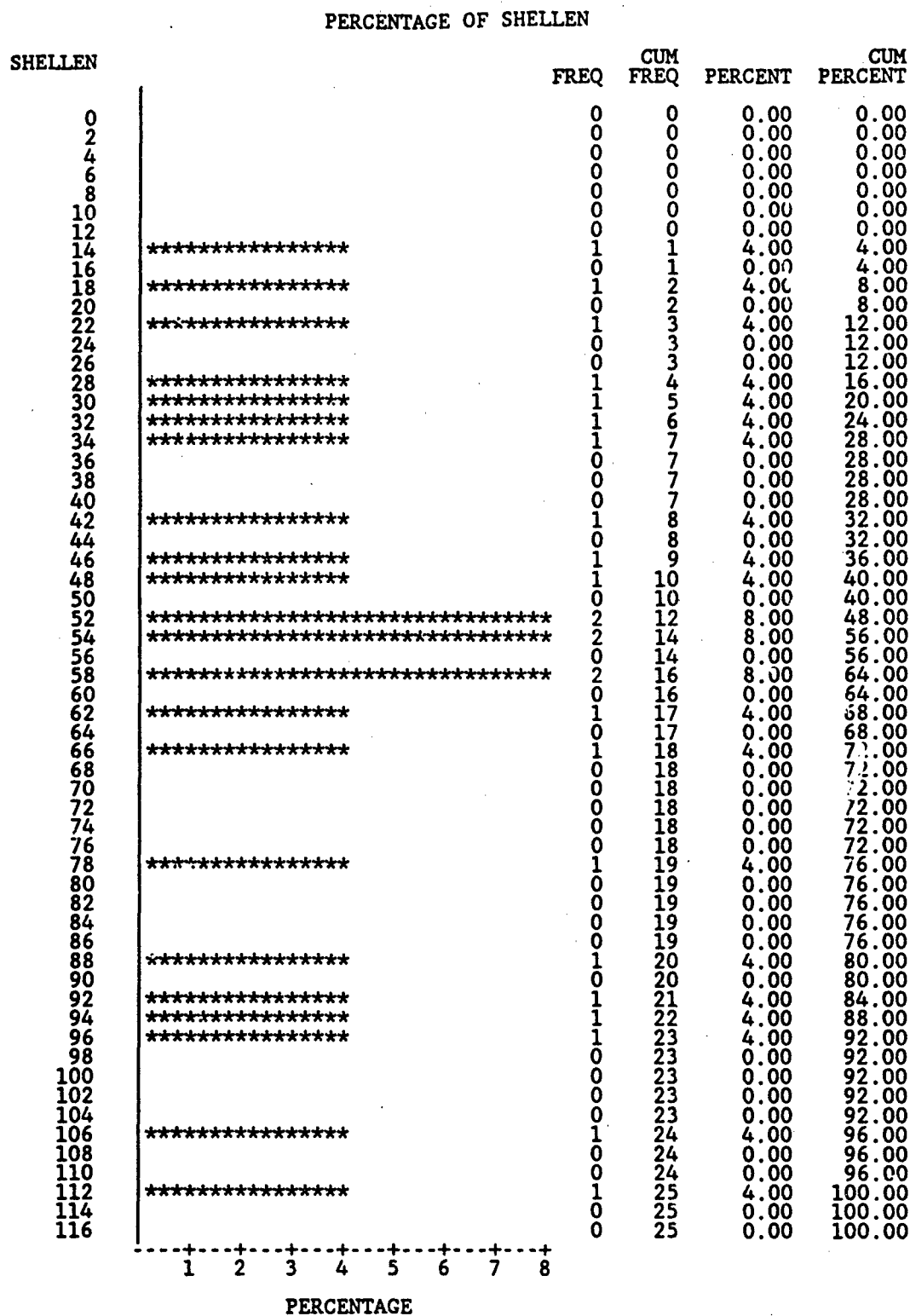


Figure 23. Length-frequency histogram for *Amblema plicata plicata*, all four sites combined, 1991

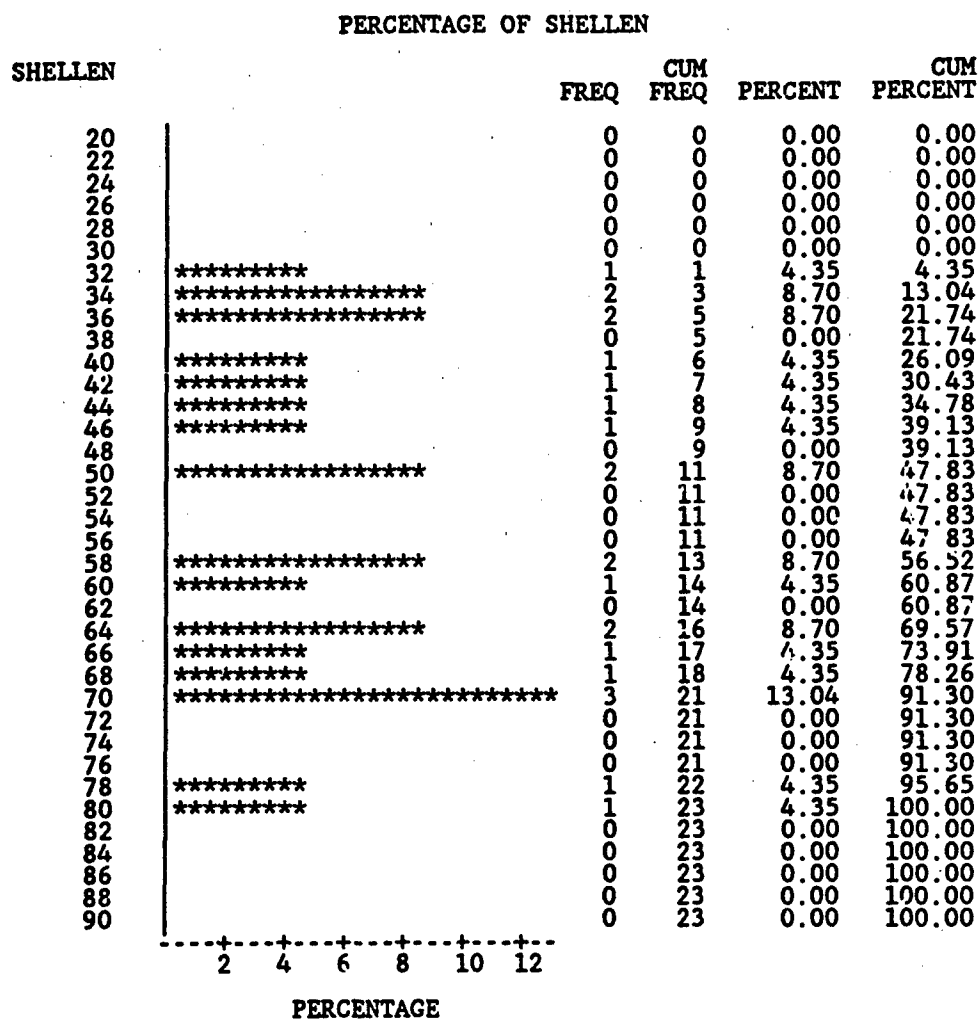


Figure 24. Length-frequency histogram for *Ellipsaria lineolata*, all four sites combined, 1991

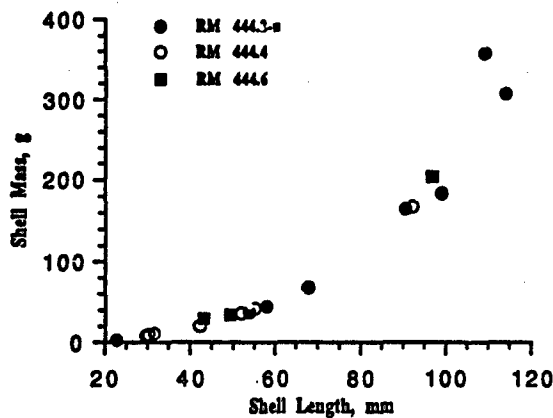
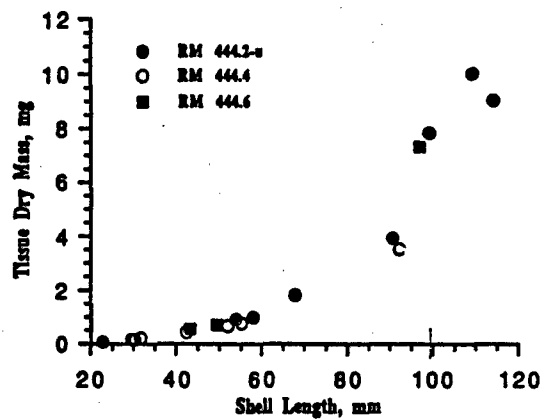
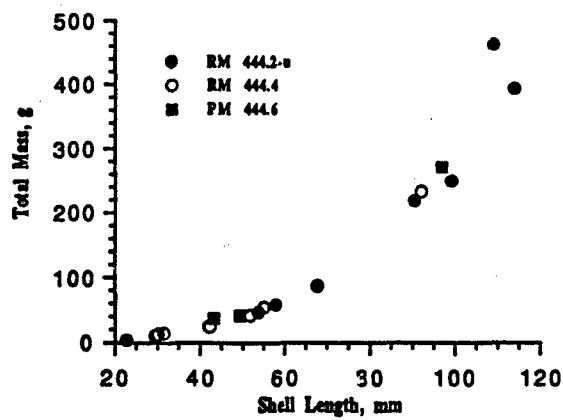


Figure 25. Condition indices for *Amblema plicata* downriver of W. H. Zimmer Station

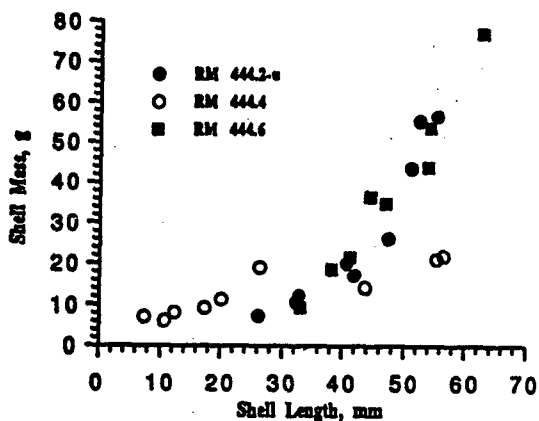
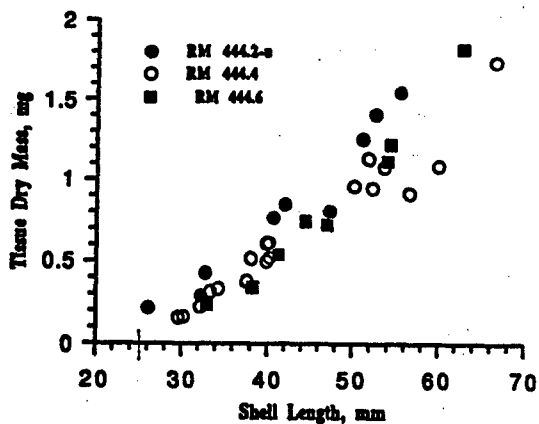
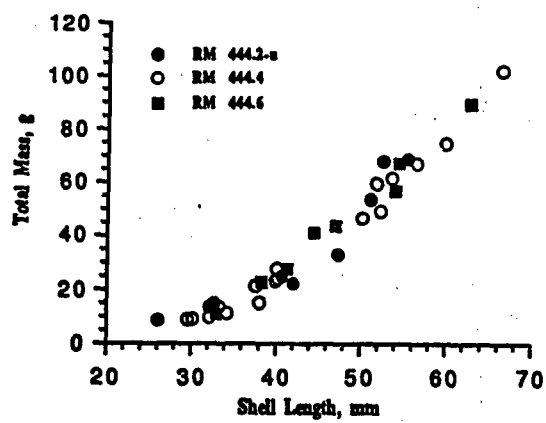


Figure 26. Condition indices for *Obliquaria reflexa* downriver of W. H. Zimmer Station

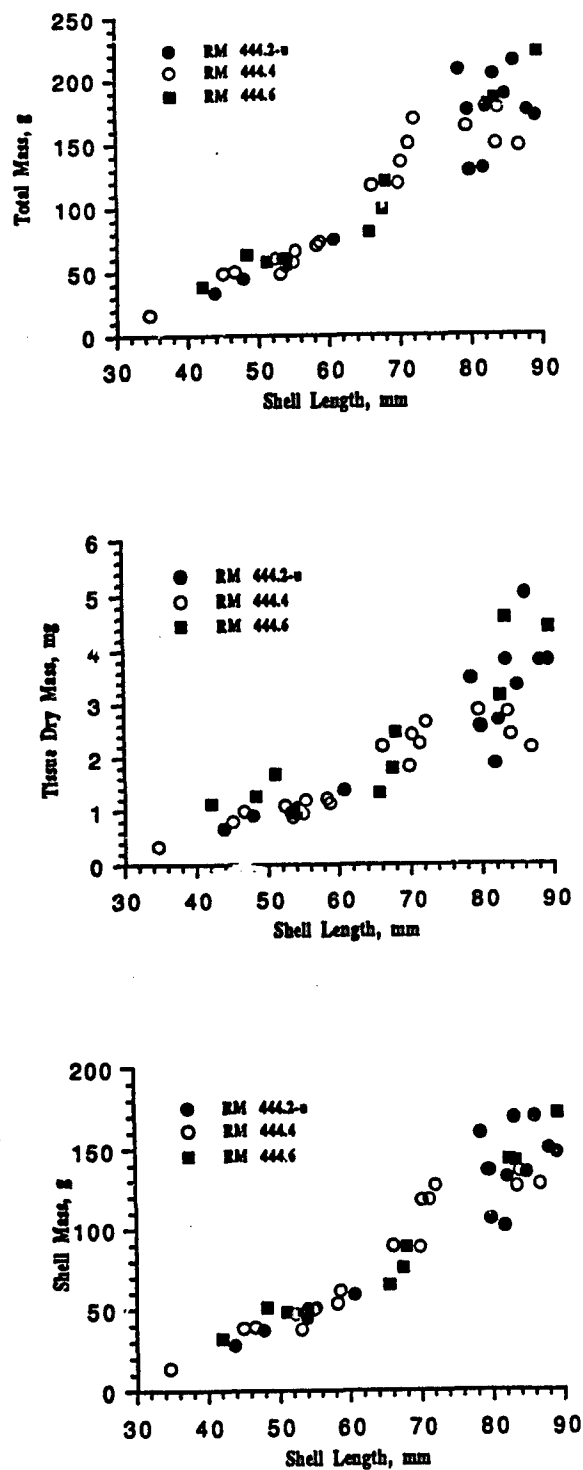


Figure 27. Condition indices for *Pleurobema cordatum* downriver of W. H. Zimmer Station

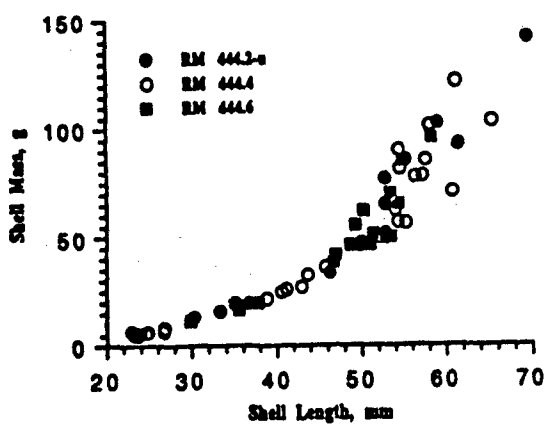
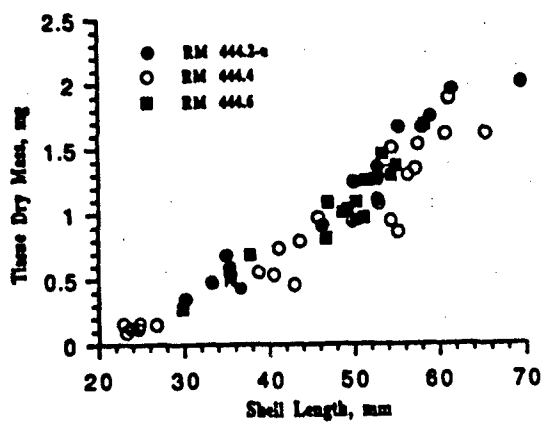
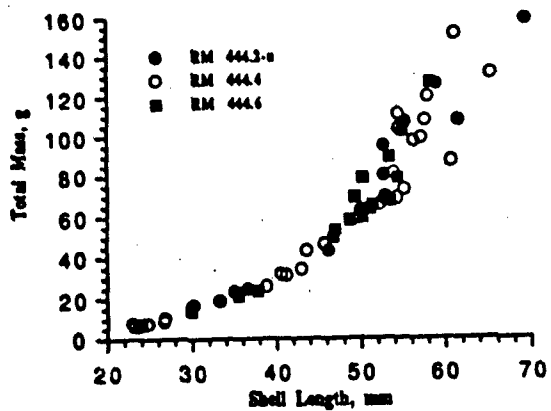
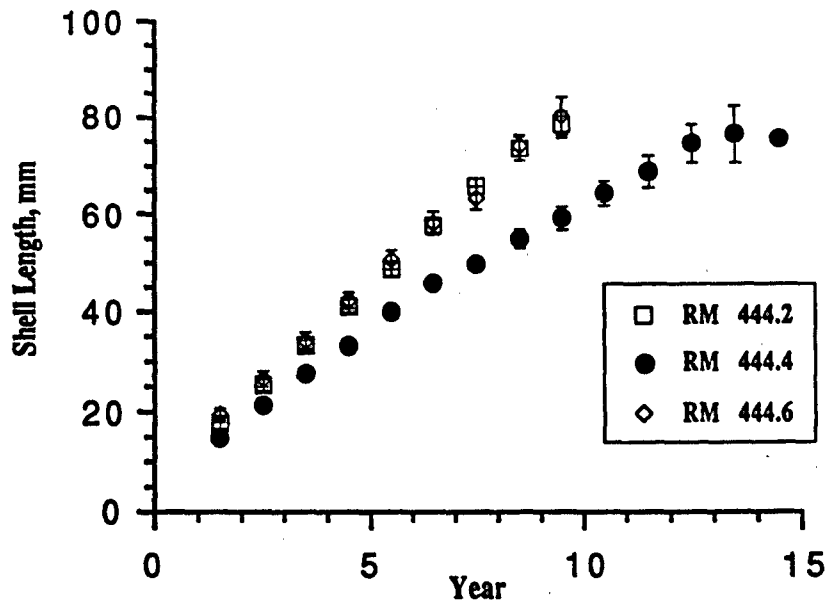


Figure 28. Condition indices for *Quadrula pustulosa* downriver of W. H. Zimmer Station

Pleurobema cordatum



Obliquaria reflexa

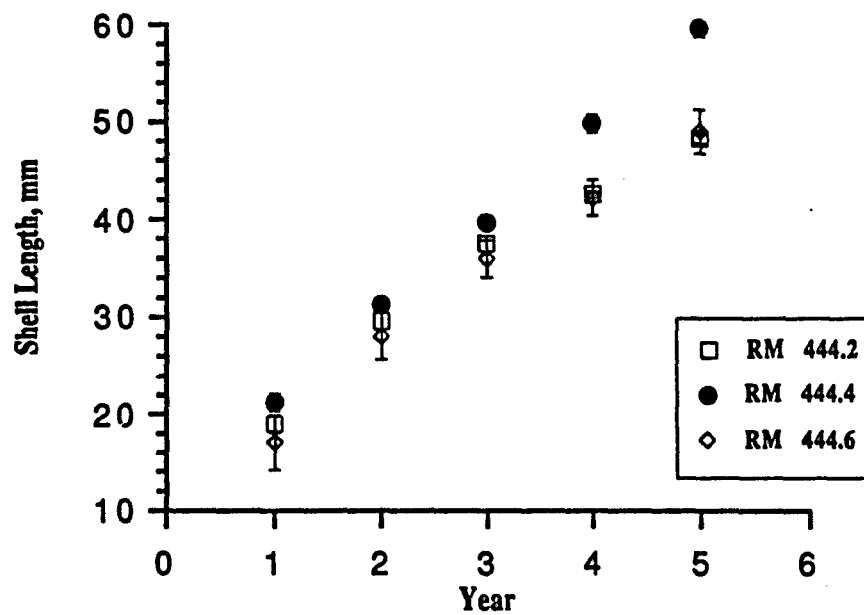


Figure 29. Growth rates for *Pleurobema cordatum* and *Obliquaria reflexa* downriver of W. H. Zimmer Station

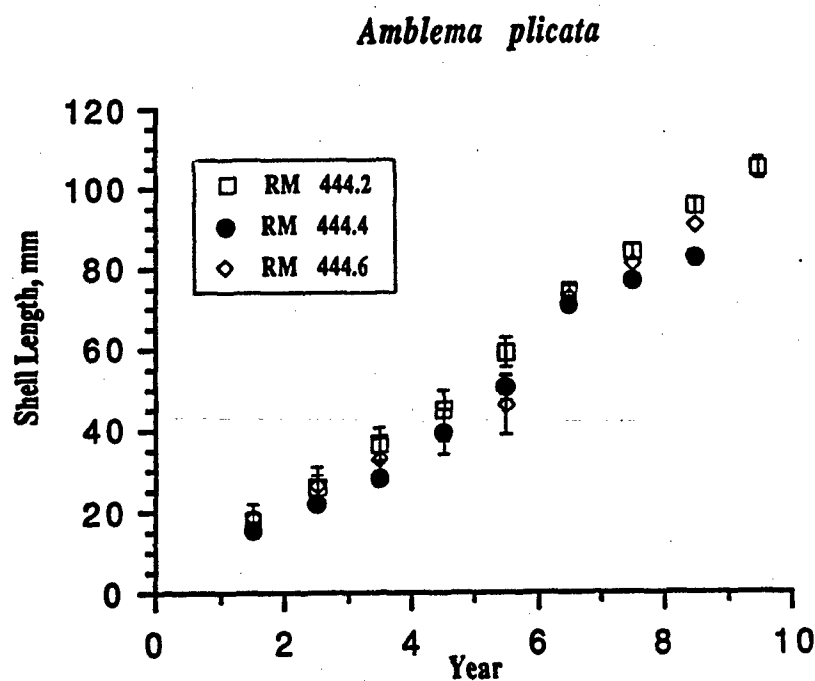
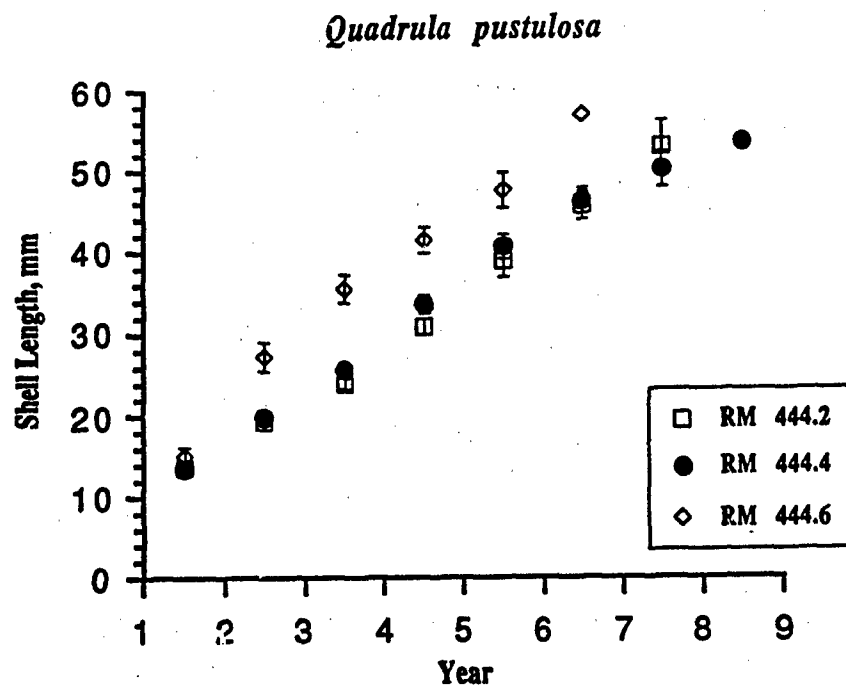
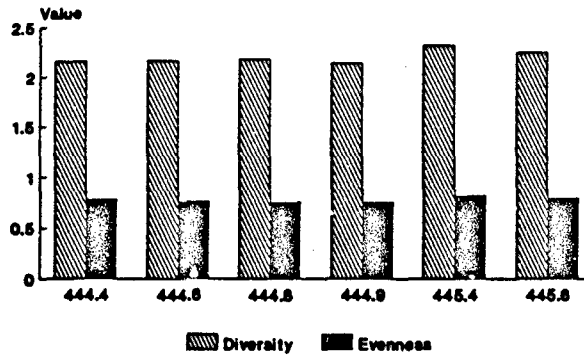


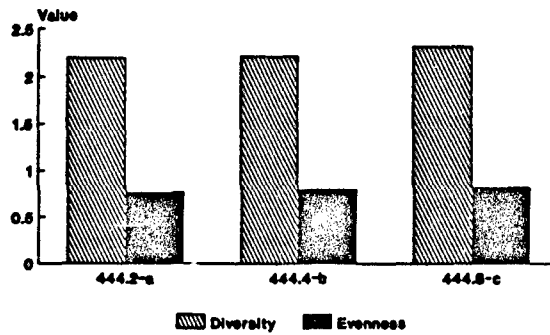
Figure 30. Growth rates for *Quadrula pustulosa* and *Amblema plicata* down-river of W. H. Zimmer Station

Qualitative Samples, 1989



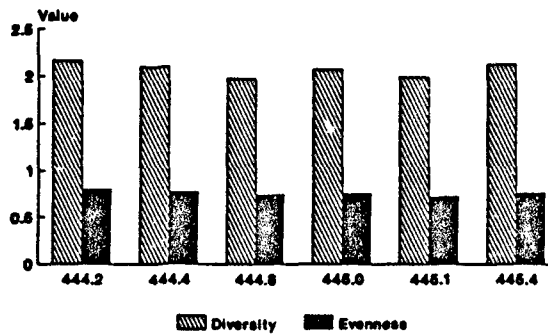
zm91-4

Qualitative Samples, 1990



zm91-8

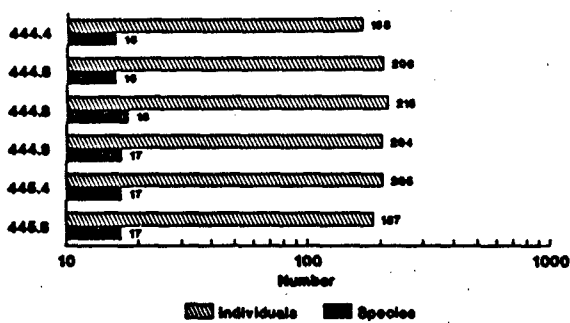
Qualitative Samples, 1991



zm91-2

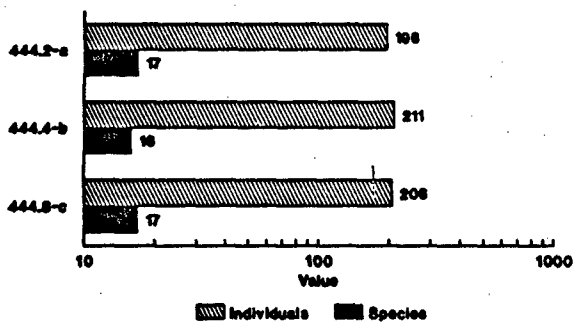
Figure 31. Species diversity and evenness--1989, 1990, and 1991

Qualitative Samples, 1989



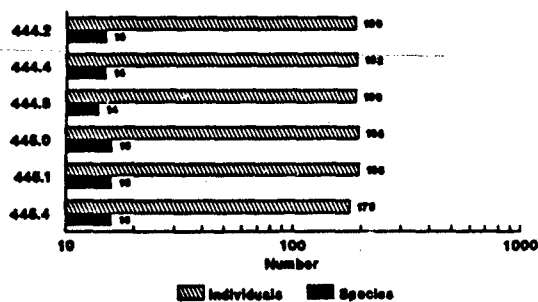
sm89-7

Qualitative Samples, 1990



sm90-8

Qualitative Samples, 1991



sm91-8

Figure 32. Total individuals and total species collected in qualitative samples--1989, 1990, and 1991

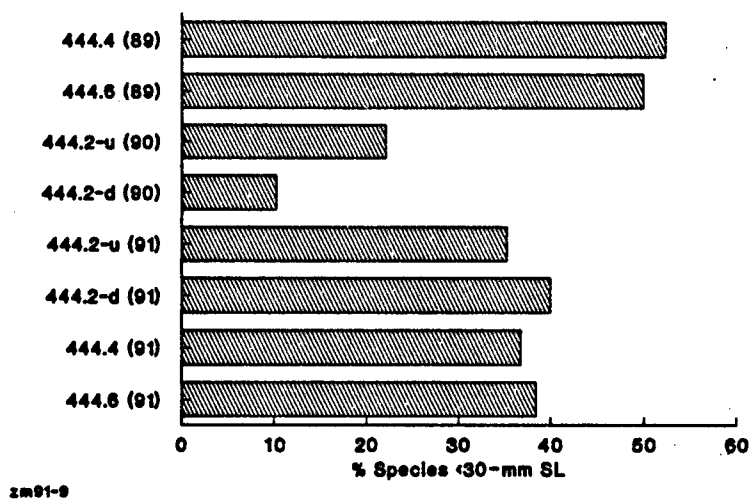
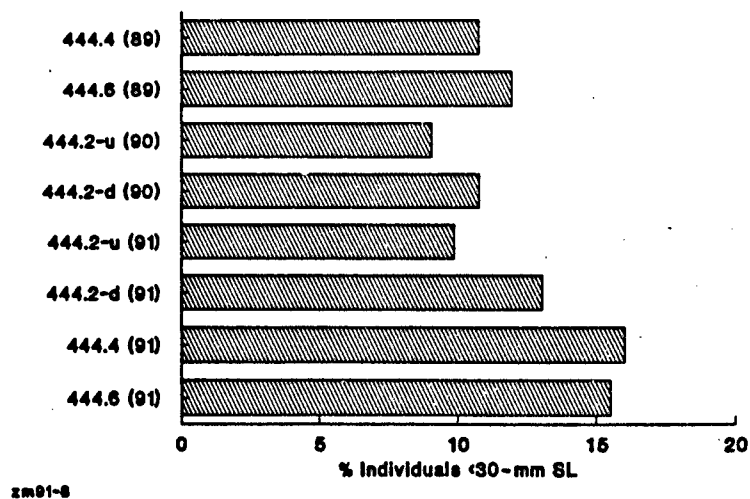


Figure 33. Percent individuals and percent species less than 30-mm total shell length (SL)--1989, 1990, and 1991

Table 1
Percent Abundance and Occurrence for Bivalves Collected Using
Qualitative Methods at Six Sites at the Mussel Bed Immediately
Downriver of W. H. Zimmer Station, 1991

| Species | Abundance | Occurrence |
|--|-----------|------------|
| <i>Quadrula pustulosa pustulosa</i> (L. Lea, 1831) | 22.79 | 88.89 |
| <i>Amblema plicata plicata</i> (Say, 1817) | 20.25 | 80.56 |
| <i>Pleurobema cordatum</i> (Rafinesque, 1820) | 18.49 | 80.56 |
| <i>Quadrula metanevra</i> (Rafinesque, 1820) | 9.11 | 59.72 |
| <i>Megalomias nervosa</i> (Rafinesque, 1820) | 6.13 | 41.67 |
| <i>Elliptio crassidens</i> (Lamarck, 1819) | 4.73 | 48.61 |
| <i>Obliquaria reflexa</i> Rafinesque, 1820 | 4.65 | 41.67 |
| <i>Ellipsaria lineolata</i> (Rafinesque, 1820) | 3.33 | 38.89 |
| <i>Fusconaia ebena</i> (L. Lea, 1831) | 1.93 | 25.00 |
| <i>Quadrula quadrula</i> (Rafinesque, 1820) | 1.31 | 18.06 |
| <i>Plethobasus cyphus</i> (Rafinesque, 1820) | 1.23 | 15.28 |
| <i>Quadrula nodulata</i> (Rafinesque, 1820) | 1.23 | 16.67 |
| <i>Cyclonaias tuberculata</i> (Rafinesque, 1820) | 1.14 | 16.67 |
| <i>Tritogonia verrucosa</i> (Rafinesque, 1820) | 0.88 | 12.50 |
| <i>Potamilus elatus</i> (Say, 1817) | 0.70 | 9.72 |
| <i>Obovaria olivaria</i> (Rafinesque, 1820) | 0.61 | 8.33 |
| <i>Lampsilis ovata</i> (Say, 1817) | 0.53 | 8.33 |
| <i>Elliptio dilatata</i> (Rafinesque, 1820) | 0.26 | 4.17 |
| <i>Fusconaia flava</i> (Rafinesque, 1820) | 0.26 | 2.78 |
| <i>Actinonaias ligamentina</i> (Lamarck, 1819) | 0.18 | 2.78 |
| <i>Strophitus undulatus</i> (Say, 1817) | 0.09 | 1.39 |
| <i>Truncilla donaciformis</i> (L. Lea, 1828) | 0.09 | 1.39 |
| <i>Ligumia recta</i> (Lamarck, 1819) | 0.09 | 1.39 |
| Total individuals | 1,141 | |
| Total species | 23 | |
| Total samples | 72 | |

Table 2
Percent Abundance for Bivalves Collected Using Qualitative
Methods at Six Sites at the Mussel Bed Immediately Downriver of
W. H. Zimmer Station, 1991

| Species | River Mile | | | | | |
|------------------------|------------|-------|-------|-------|-------|-------|
| | 444.2 | 444.4 | 444.8 | 445.0 | 445.1 | 445.4 |
| <i>Q. pustulosa</i> | 20.63 | 28.13 | 26.32 | 25.64 | 15.31 | 20.67 |
| <i>A. plicata</i> | 14.29 | 17.71 | 12.11 | 20.00 | 40.82 | 15.64 |
| <i>P. cordatum</i> | 23.81 | 19.79 | 23.68 | 22.56 | 4.08 | 17.32 |
| <i>Q. metanevra</i> | 13.23 | 10.42 | 18.95 | 9.23 | 0.51 | 2.23 |
| <i>M. nervosa</i> | 0.00 | 3.13 | 2.63 | 2.05 | 8.67 | 21.23 |
| <i>E. crassidens</i> | 7.41 | 3.13 | 3.16 | 4.62 | 1.53 | 8.94 |
| <i>O. reflexa</i> | 4.23 | 4.69 | 3.68 | 3.08 | 10.71 | 1.12 |
| <i>E. lineolata</i> | 3.17 | 1.56 | 4.21 | 2.05 | 5.10 | 3.91 |
| <i>F. ebena</i> | 3.17 | 1.56 | 1.05 | 3.59 | 1.02 | 1.12 |
| <i>Q. quadrula</i> | 1.59 | 2.08 | 0.00 | 1.03 | 2.04 | 1.12 |
| <i>Q. nodulata</i> | 1.06 | 1.04 | 1.05 | 1.03 | 3.06 | 0.00 |
| <i>P. cyphus</i> | 1.06 | 3.65 | 0.53 | 2.05 | 0.00 | 0.00 |
| <i>C. tuberculata</i> | 1.59 | 1.56 | 0.53 | 1.54 | 0.51 | 1.12 |
| <i>T. verrucosa</i> | 0.00 | 0.00 | 1.58 | 0.51 | 2.55 | 0.56 |
| <i>P. alatus</i> | 0.00 | 0.00 | 0.00 | 0.00 | 3.06 | 1.12 |
| <i>O. olivaria</i> | 3.70 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| <i>L. ventricosa</i> | 0.00 | 0.52 | 0.00 | 0.51 | 0.00 | 2.23 |
| <i>E. dilatata</i> | 0.53 | 0.00 | 0.00 | 0.00 | 0.00 | 1.12 |
| <i>F. flava</i> | 0.00 | 1.04 | 0.00 | 0.51 | 0.00 | 0.00 |
| <i>A. ligamentina</i> | 0.53 | 0.00 | 0.53 | 0.00 | 0.00 | 0.00 |
| <i>L. recta</i> | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.56 |
| <i>S. undulatus</i> | 0.00 | 0.00 | 0.00 | 0.00 | 0.51 | 0.00 |
| <i>T. donaciformis</i> | 0.00 | 0.00 | 0.00 | 0.00 | 0.51 | 0.00 |
| Total individuals | 189 | 192 | 190 | 195 | 196 | 179 |
| Total species | 15 | 15 | 14 | 16 | 16 | 16 |
| Species diversity | 2.16 | 2.10 | 1.97 | 2.07 | 1.99 | 2.12 |
| Evenness | 0.80 | 0.77 | 0.74 | 0.75 | 0.72 | 0.76 |
| Dominance | 0.14 | 0.16 | 0.18 | 0.17 | 0.21 | 0.15 |

Table 3
Frequency of Occurrence for Bivalves Collected Using Qualitative
Methods at Six Sites at the Mussel Bed Immediately Downriver of
W. H. Zimmer Station, 1991

| Species | River Mile | | | | | |
|------------------------|------------|-------|-------|--------|--------|-------|
| | 444.2 | 444.4 | 444.8 | 445.0 | 445.1 | 445.4 |
| <i>Q. pustulosa</i> | 83.33 | 91.67 | 91.67 | 100.00 | 83.33 | 83.33 |
| <i>P. cordatum</i> | 91.67 | 91.67 | 83.33 | 91.67 | 41.67 | 83.33 |
| <i>A. plicata</i> | 83.33 | 66.67 | 75.00 | 75.00 | 100.00 | 83.33 |
| <i>Q. metanevra</i> | 91.67 | 75.00 | 83.33 | 75.00 | 8.33 | 25.00 |
| <i>E. crassidens</i> | 66.67 | 41.67 | 50.00 | 58.33 | 16.67 | 58.33 |
| <i>O. reflexa</i> | 41.67 | 41.67 | 41.67 | 41.67 | 75.00 | 8.33 |
| <i>M. nervosa</i> | 0.00 | 41.67 | 33.33 | 25.00 | 75.00 | 75.00 |
| <i>E. lineolata</i> | 41.67 | 25.00 | 50.00 | 25.00 | 50.00 | 41.67 |
| <i>F. ebena</i> | 50.00 | 16.67 | 16.67 | 33.33 | 16.67 | 16.67 |
| <i>Q. quadrula</i> | 16.67 | 33.33 | 0.00 | 16.67 | 25.00 | 16.67 |
| <i>C. tuberculata</i> | 16.67 | 25.00 | 8.33 | 25.00 | 8.33 | 16.67 |
| <i>Q. nodulata</i> | 16.67 | 16.67 | 16.67 | 16.67 | 33.33 | 0.00 |
| <i>P. cyphus</i> | 16.67 | 33.33 | 8.33 | 33.33 | 0.00 | 0.00 |
| <i>T. verrucosa</i> | 0.00 | 0.00 | 16.67 | 8.33 | 41.67 | 8.33 |
| <i>P. alatus</i> | 0.00 | 0.00 | 0.00 | 0.00 | 41.67 | 16.67 |
| <i>L. ventricosa</i> | 0.00 | 8.33 | 0.00 | 8.33 | 0.00 | 33.33 |
| <i>O. olivaria</i> | 50.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| <i>E. dilatata</i> | 8.33 | 0.00 | 0.00 | 0.00 | 0.00 | 16.67 |
| <i>F. flava</i> | 0.00 | 8.33 | 0.00 | 8.33 | 0.00 | 0.00 |
| <i>A. ligamentina</i> | 8.33 | 0.00 | 8.33 | 0.00 | 0.00 | 0.00 |
| <i>L. recta</i> | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8.33 |
| <i>S. undulatus</i> | 0.00 | 0.00 | 0.00 | 0.00 | 8.33 | 0.00 |
| <i>T. donaciformis</i> | 0.00 | 0.00 | 0.00 | 0.00 | 8.33 | 0.00 |
| Total samples | 12 | 12 | 12 | 12 | 12 | 12 |

Table 4
Total Bivalve Density and Biomass (Standard Error) at Four Sites
at the Mussel Bed Immediately Downriver of W. H. Zimmer
Station, 1991

| Site | <i>C. fluminea</i> | | Unionidae | |
|---------------------------------|--------------------|--------|-----------|--------|
| | Mean | SE | Mean | SE |
| Density Data (Individuals/sq m) | | | | |
| 444.2-u | 828.00 | 68.02 | 40.40 | 5.97 |
| 444.2-d | 472.00 | 116.05 | 33.60 | 10.96 |
| 444.4 | 665.00 | 34.03 | 52.40 | 8.93 |
| 444.6 | 780.00 | 31.97 | 23.20 | 5.05 |
| Biomass Data (g/sq m) | | | | |
| 444.2-u | 3,148.04 | 356.11 | 3,957.28 | 629.38 |
| 444.2-d | 2,497.52 | 824.82 | 2,715.04 | 774.07 |
| 444.4 | 3,749.24 | 240.89 | 3,515.20 | 650.53 |
| 444.6 | 3,898.72 | 123.88 | 1,413.12 | 272.59 |

Table 5
Percent Species Abundance and Summary Statistics for Bivalves
Collected Using Quantitative Methods at Four Sites at the Mussel
Bed Immediately Downriver of W. H. Zimmer Station, 1991

| Species | Collection Site | | | | |
|------------------------|-----------------|---------|-------|-------|-------|
| | 444.2-u | 444.2-d | 444.4 | 444.6 | Total |
| <i>O. pustulosa</i> | 19.19 | 26.19 | 26.56 | 32.14 | 25.34 |
| <i>P. cordatum</i> | 28.28 | 17.86 | 18.75 | 17.86 | 20.98 |
| <i>O. reflexa</i> | 10.10 | 13.10 | 16.41 | 14.29 | 13.62 |
| <i>A. plicata</i> | 9.09 | 5.95 | 5.47 | 7.14 | 6.81 |
| <i>O. metanevra</i> | 3.03 | 10.71 | 7.81 | 5.36 | 6.81 |
| <i>E. lineolata</i> | 10.10 | 0.00 | 7.81 | 5.36 | 6.27 |
| <i>T. donaciformis</i> | 1.01 | 2.38 | 4.69 | 3.57 | 3.00 |
| <i>O. nodulata</i> | 2.02 | 4.76 | 1.56 | 3.57 | 2.72 |
| <i>T. truncata</i> | 0.00 | 4.76 | 2.34 | 5.36 | 2.72 |
| <i>F. ebena</i> | 3.03 | 2.38 | 2.34 | 0.00 | 2.18 |
| <i>E. crassidens</i> | 2.02 | 3.57 | 0.78 | 1.79 | 1.91 |
| <i>O. quadrula</i> | 2.02 | 2.38 | 0.78 | 1.79 | 1.63 |
| <i>M. nervosa</i> | 3.03 | 2.38 | 0.78 | 0.00 | 1.63 |
| <i>F. flava</i> | 2.02 | 1.19 | 0.78 | 0.00 | 1.09 |
| <i>P. alatus</i> | 3.03 | 1.19 | 0.00 | 0.00 | 1.09 |
| <i>P. cyphus</i> | 1.01 | 1.19 | 0.78 | 0.00 | 0.82 |
| <i>L. ventricosa</i> | 1.01 | 0.00 | 0.78 | 0.00 | 0.54 |
| <i>E. dilatata</i> | 0.00 | 0.00 | 0.00 | 1.79 | 0.27 |
| <i>L. fragilis</i> | 0.00 | 0.00 | 0.78 | 0.00 | 0.27 |
| <i>A. ligamentina</i> | 0.00 | 0.00 | 0.78 | 0.00 | 0.27 |
| Total individuals | 99 | 84 | 128 | 56 | 367 |
| Total species | 16 | 15 | 18 | 12 | 20 |
| Diversity | 2.23 | 2.25 | 2.21 | 2.06 | 2.30 |
| Dominance | 0.14 | 0.13 | 0.15 | 0.16 | 0.14 |
| Evenness | 0.80 | 0.83 | 0.76 | 0.83 | 0.77 |
| % Individuals <30 mm | 9.90 | 13.09 | 16.03 | 15.52 | 13.64 |
| % Species <30 mm | 35.29 | 40.00 | 36.84 | 38.46 | 47.62 |

Table 6
Frequency of Occurrence of Mussels Collected Using Quantitative
Methods at Four Sites at the Mussel Bed Immediately Downriver
of W. H. Zimmer Station, 1991

| Species | Collection Site | | | | |
|------------------------|-----------------|---------|--------|-------|-------|
| | 444.2-u | 444.2-d | 444.4 | 444.6 | Total |
| <i>Q. pustulosa</i> | 80.00 | 40.00 | 100.00 | 80.00 | 75.00 |
| <i>P. cordatum</i> | 80.00 | 50.00 | 100.00 | 60.00 | 72.50 |
| <i>O. reflexa</i> | 70.00 | 40.00 | 70.00 | 20.00 | 50.00 |
| <i>A. plicata</i> | 60.00 | 30.00 | 50.00 | 30.00 | 42.50 |
| <i>E. lineolata</i> | 70.00 | 0.00 | 40.00 | 30.00 | 35.00 |
| <i>Q. metanevra</i> | 30.00 | 40.00 | 50.00 | 20.00 | 35.00 |
| <i>Q. nodulata</i> | 20.00 | 30.00 | 20.00 | 20.00 | 22.50 |
| <i>T. donaciformis</i> | 10.00 | 20.00 | 40.00 | 20.00 | 22.50 |
| <i>E. crassidens</i> | 20.00 | 30.00 | 10.00 | 10.00 | 17.50 |
| <i>F. ebena</i> | 20.00 | 20.00 | 30.00 | 0.00 | 17.50 |
| <i>T. truncata</i> | 0.00 | 30.00 | 10.00 | 20.00 | 15.00 |
| <i>Q. quadrula</i> | 20.00 | 10.00 | 10.00 | 10.00 | 12.50 |
| <i>C. fluminea</i> | 10.00 | 0.00 | 20.00 | 20.00 | 12.50 |
| <i>M. nervosa</i> | 20.00 | 20.00 | 10.00 | 0.00 | 12.50 |
| <i>P. alatus</i> | 20.00 | 10.00 | 0.00 | 0.00 | 7.50 |
| <i>P. cyphus</i> | 10.00 | 10.00 | 10.00 | 0.00 | 7.50 |
| <i>F. flava</i> | 10.00 | 10.00 | 10.00 | 0.00 | 7.50 |
| <i>L. ventricosa</i> | 10.00 | 0.00 | 10.00 | 0.00 | 5.00 |
| <i>A. ligamentina</i> | 0.00 | 0.00 | 10.00 | 0.00 | 2.50 |
| <i>L. fragilis</i> | 0.00 | 0.00 | 10.00 | 0.00 | 2.50 |
| <i>E. dilatata</i> | 0.00 | 0.00 | 0.00 | 10.00 | 2.50 |
| Total individuals | 10 | 10 | 10 | 10 | 40 |

Table 7
Percent Abundance and Frequency of Occurrence of Freshwater Mussels Collected, Ohio
River Mile 444.2-445.6

| Species | Qualitative ¹ | | Quantitative ¹ | | Percent Abundance ² |
|--|--------------------------|------------|---------------------------|------------|--------------------------------|
| | Abundance | Occurrence | Abundance | Occurrence | |
| <i>Pleurobema cordatum</i> (Rafinesque, 1820) | 20.30 | 82.41 | 13.60 | 60.00 | 11.27 |
| <i>Quadrula p. pustulosa</i> (I. Lea, 1931) | 18.74 | 89.81 | 26.29 | 85.00 | 12.34 |
| <i>Quadrula metanavra</i> (Rafinesque, 1820) | 15.63 | 74.07 | 7.66 | 43.00 | 15.38 |
| <i>Amblema p. plicata</i> (Say 1817) | 10.01 | 73.15 | 8.23 | 46.00 | 8.76 |
| <i>Obliquaria reflexa</i> Rafinesque, 1820 | 7.45 | 63.89 | 9.14 | 54.00 | 13.99 |
| <i>Ellipsaria lineolata</i> (Rafinesque, 1820) | 4.62 | 44.44 | 5.94 | 39.00 | 1.93 |
| <i>Megalonaia nervosa</i> (Rafinesque, 1820) | 4.28 | 41.67 | 1.49 | 12.00 | 3.33 |
| <i>Elliptio crassidens</i> (Lamarck, 1819) | 4.00 | 37.96 | 3.09 | 22.00 | 6.21 |
| <i>Quadrula quadrula</i> (Rafinesque, 1820) | 2.78 | 30.56 | 2.29 | 18.00 | 10.65 |
| <i>Fusconaia ebena</i> (I. Lea, 1831) | 2.34 | 37.04 | 2.17 | 14.00 | 0.90 |
| <i>Quadrula nodulata</i> (Rafinesque, 1820) | 2.22 | 24.07 | 2.29 | 20.00 | 2.76 |
| <i>Plethobasus cyphus</i> (Rafinesque, 1820) | 1.50 | 18.52 | 0.69 | 6.00 | 0.45 |
| <i>Fusconaia flava</i> (Rafinesque, 1820) | 1.50 | 21.30 | 3.77 | 25.00 | 5.06 |
| <i>Cyclonaias tuberculata</i> (Rafinesque, 1820) | 0.89 | 12.96 | 1.14 | 9.00 | 0.95 |
| <i>Potamilus alatus</i> (Say, 1817) | 0.83 | 12.04 | 0.57 | 5.00 | 1.03 |
| <i>Truncilla truncata</i> Rafinesque, 1820 | 0.72 | 12.19 | 7.31 | 57.00 | 1.07 |
| <i>Tritogonia verrucosa</i> (Rafinesque, 1820) | 0.61 | 10.19 | 0.34 | 3.00 | 0.78 |
| <i>Lampsilis ovata</i> (Say, 1817) | 0.56 | 9.26 | 0.11 | 1.00 | 0.25 |
| <i>Actinonaias ligamentina</i> (Lamarck, 1819) | 0.28 | 4.63 | 1.14 | 8.00 | 0.37 |
| <i>Leptodea fragilis</i> (Rafinesque, 1820) | 0.22 | 3.70 | 1.03 | 9.00 | 1.40 |
| <i>Ligumia recta</i> (Lamarck, 1819) | 0.17 | 2.78 | 0.46 | 4.00 | 0.08 |
| <i>Lasemigona costata</i> (Rafinesque, 1820) | 0.11 | 1.85 | 0.11 | 1.00 | 0.04 |
| <i>Elliptio dilatata</i> (Rafinesque, 1820) | 0.11 | 1.85 | -- | -- | 0.37 |
| <i>Lampsilis abrupta</i> (Say, 1831) | 0.06 | 0.93 | -- | -- | -- |
| <i>Anodonta grandis</i> Say, 1829 | 0.06 | 0.93 | -- | -- | 0.08 |
| <i>Truncilla donaciformis</i> (I. Lea, 1828) | -- | -- | 1.03 | 8.00 | 0.12 |

(Continued)

¹ As reported in Miller and Payne (1991). Samples were collected in July 1989 and September 1990.

² As reported in Stansbery and Cooney (1985). Samples were collected by hand, by use of a brail, and by divers.

Table 7 (Concluded)

| Species | Qualitative | | Quantitative | | Percent Abundance |
|---|-------------|------------|--------------|------------|-------------------|
| | Abundance | Occurrence | Abundance | Occurrence | |
| <i>Pleurobema coccineum</i> (Conrad, 1834) ¹ | -- | -- | 0.11 | 1.00 | 0.29 |
| <i>Potamilus ohioensis</i> (Rafinesque, 1820) | -- | -- | -- | -- | 0.08 |
| <i>Toxolasma parvus</i> (Barnes, 1823) | -- | -- | -- | -- | 0.04 |
| <i>Anodonta suborbiculata</i> Say, 1931 | -- | -- | -- | -- | 0.04 |
| Total mussels | 1,798 | | 875 | | 2,432 |
| Total samples | 108 | | 100 | | -- |
| Total sites | 9 | | 4 | | -- |
| Total species | 25 | | 24 | | 29 |
| Species diversity ($\log_{2.3026}$) | 2.40 | | 2.48 | | 2.54 |
| Maximum diversity ($\log_{2.3026}$ richness) | 3.22 | | 3.18 | | 3.37 |
| Evenness (J) | 0.74 | | 0.78 | | 0.75 |

¹ *Pleurobema coccineum* (Conrad, 1834) was referred to as *P. sintoxia* by Stansbery and Cooney (1985).

Table 8
Summary Statistics for Freshwater Mussels Collected Using
Qualitative and Quantitative Methods, Ohio River Mile 444.2-
445.6, July 1989 and September 1990

| Location | Total Quadrats | Total Mussels | Total Species | Species Diversity | Evenness | % Individuals <30-mm SL |
|-----------------------------|-------------------|------------------|------------------|----------------------|----------|----------------------------|
| Qualitative Samples | | | | | | |
| 444.2-a | N/A | 196 | 17 | 2.20 | 0.78 | N/A |
| 444.2-b | N/A | 211 | 16 | 2.22 | 0.80 | N/A |
| 444.2-c | N/A | 206 | 17 | 2.32 | 0.82 | N/A |
| 444.4 | N/A | 168 | 16 | 2.16 | 0.78 | N/A |
| 444.6 | N/A | 206 | 16 | 2.17 | 0.78 | N/A |
| 444.8 | N/A | 215 | 18 | 2.18 | 0.76 | N/A |
| 444.9 | N/A | 204 | 17 | 2.14 | 0.76 | N/A |
| 445.4 | N/A | 205 | 17 | 2.32 | 0.82 | N/A |
| 445.6 | N/A | 187 | 17 | 2.24 | 0.79 | N/A |
| Quantitative Samples | | | | | | |
| 444.2-u | 20 | 99 | 18 | 2.50 | 0.86 | 9.1 |
| 444.2-d | 20 | 157 | 20 | 2.49 | 0.83 | 10.8 |
| 444.4 | 30 | 344 | 21 | 2.32 | 0.76 | 10.8 |
| 444.6 | 30 | 275 | 20 | 2.40 | 0.90 | 12.0 |

Table 9
Summary Statistics for Freshwater Mussels and *Corbicula*
***fluminea*, Ohio River Mile 444.2-445.6, July 1989 and September**
1990

| Location | Subsite | Freshwater Mussels | | SD | <i>C. fluminea</i> | |
|----------|---------|--------------------|---------|------|--------------------|-------|
| | | Species | Density | | Density | SD |
| 444.2-u | 1 | 6 | 4.4 | 6.8 | 66.8 | 67.7 |
| | 2 | 18 | 35.2 | 25.8 | 161.6 | 81.5 |
| 444.2-d | 1 | 18 | 31.2 | 9.8 | 613.2 | 92.4 |
| | 2 | 14 | 22.0 | 4.3 | 857.6 | 88.7 |
| 444.4 | 1 | 6 | 30.0 | 15.2 | 1,092.4 | 358.4 |
| | 2 | 14 | 39.6 | 28.1 | 1,238.0 | 258.3 |
| | 3 | 17 | 40.4 | 15.8 | 1,352.8 | 96.1 |
| 444.6 | 1 | 20 | 46.4 | 17.1 | 1,009.2 | 110.3 |
| | 2 | 16 | 52.4 | 13.9 | 939.6 | 141.1 |
| | 3 | 16 | 38.8 | 10.7 | 796.8 | 140.6 |

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0703-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204 Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
January 1993

3. REPORT TYPE AND DATES COVERED
Final report

4. TITLE AND SUBTITLE

Phase II Studies: Impacts of Commercial Navigation
Traffic on Freshwater Mussels at the W. H. Zimmer
Station, 1991 Studies

5. FUNDING NUMBERS

C 108

6. AUTHOR(S)

Andrew C. Miller, Barry S. Payne

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Engineer Waterways Experiment Station
Environmental Laboratory, 3909 Halls Ferry Road
Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION
REPORT NUMBER

Technical Report
EL-93-2

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Mussel Mitigation Trust
139 E. 4th Street
Cincinnati, OH 45202

10. SPONSORING/MONITORING
AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

Qualitative and quantitative baseline data were obtained at six and four sites, respectively, at a mussel bed located on the Ohio River (river miles 444.4-445.6), near the William H. Zimmer Station, in July 1991. This information, in conjunction with additional data to be collected in future years, will be used to assess the effects of coal deliveries by barge on freshwater mussels (Family: Unionidae). The station began commercial operation in March 1991. Total species richness (23) was similar to that at other large-river mussel beds. The unionid fauna consisted almost entirely of thick-shelled species and was dominated by *Quadrula pustulosa* (22.79 percent), *Amblema plicata plicata* (20.25 percent), and *Pleurobema cordatum* (18.49 percent). The assemblage was characterized by an equitable distribution of species with no clear dominants. Average unionid density (23.2 to 52.4 individuals/sq m) was only slightly less than typical values at similar habitats but not substantially different from values recorded at this bed in 1989 and 1990. *Corbicula fluminea* density ranged from 472.0 to 780 individuals/sq m, which, although much greater than native unionid density, was similar to that found in most other large-river mussel beds. There was no evidence of competition (either in terms of density or biomass) between native and nonnative bivalves. Populations of dominant unionids consisted of large numbers of intermediate-sized

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14. SUBJECT TERMS

Commercial navigation traffic Unionid molluscs
Corbicula

15. NUMBER OF PAGES

67

16. PRICE CODE

17. SECURITY CLASSIFICATION
OF REPORT

UNCLASSIFIED

18. SECURITY CLASSIFICATION
OF THIS PAGE

UNCLASSIFIED

19. SECURITY CLASSIFICATION
OF ABSTRACT

20. LIMITATION OF ABSTRACT

13. (Concluded).

individuals and moderate to low numbers of juveniles and adults. All had multiple age classes and showed evidence of moderately strong recruitment by several recent year classes. Changes in background levels of water velocity and suspended sediments caused by movement of the workboat that shuttles coal to the unloader were measured. These were minor and of little significance at the mussel bed.

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